Salmon and Steelhead
Habitat Limiting Factors Report

for the

SAN JUAN ISLANDS
(Water Resource Inventory Area 2)

Prepared by:

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Olympia, Washington

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primum non noceo

the Latin phrase translated as “*do no further harm*”

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This report would not have been possible without the support and cooperation of many reviewers. In addition to the authors listed above, other reviewers of various chapters are listed below.

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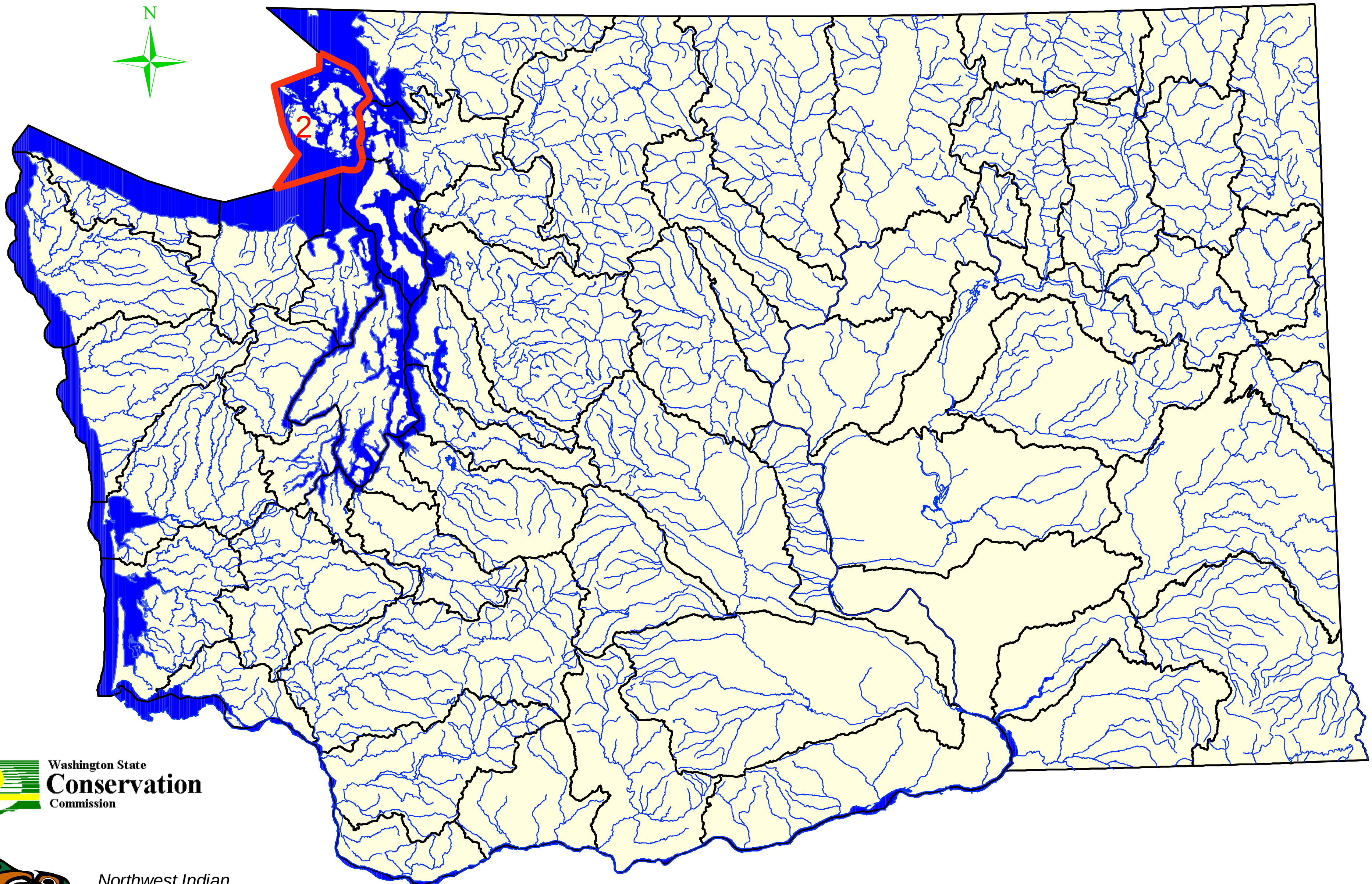
INTRODUCTION

The San Juan Islands have long been recognized for their natural beauty, mild climate, abundant and diverse living resources, and a "quality of life" unlike regions found elsewhere. These qualities have attracted increasing numbers of people to this region to live and work, and for recreation. The increasing human population has led to increased demands for housing, infrastructure, and recreational opportunities. This growth has resulted in increasing pressure on terrestrial and aquatic ecosystem processes that support all natural resources in the region. Development and other alterations of sensitive areas such as shorelines have led to dramatic losses of habitats and species declines. The most recent indicators of impacts to marine resources include the Endangered Species Act (ESA) listings of Puget Sound chinook salmon, Hood Canal summer chum salmon, bull trout, and petitions to list Orca whales in the marine waters of the San Juan Islands and Puget Sound. These ESA listings have led to increasing efforts in the development of watershed and salmon recovery plans. The marine environment has only recently been recognized as a part of individual watersheds and historical efforts to protect salmonids have primarily focused on the freshwater, reproductive and rearing phases of salmon life history.

The San Juan Islands lie largely in the central portion of the Evolutionary Significant Units for Puget Sound anadromous salmonids including ESA listed chinook. Maps illustrating these ESUs can be found in Appendix C.

Most of what is contained in this report is a consolidation of previously reported information and taking an ecosystem approach in the assessment enabled us to summarize what we know about the nearshore ecosystem, identify data gaps, and draw important and meaningful conclusions and recommendations. However, many of the conclusions and recommendations found in this report have been reported previously.

Figure 1: Location of WRIA 2 in Washington State



Washington State
Conservation
Commission

Northwest Indian
Fisheries Commission

Location of WRIA 2 outlined in Red

EXECUTIVE SUMMARY

Many stocks of the wild salmonid populations in the Puget Sound ecoregion have declined. In March 1999, the National Marine Fisheries Service (NMFS) listed Puget Sound chinook salmon as a "Threatened" species under the Endangered Species Act (ESA). In November 1999, the U.S. Fish and Wildlife Service (USFWS) listed bull trout as a "Threatened" species under the ESA.

The San Juan Islands includes in excess of 85 identified freshwater streams. Williams (1975) identified approximately 100 miles of stream habitat in the Islands but did not address accessibility issues for anadromous salmonids. The WDNR hydrolayer identifies a minimum of 83 streams on Orcas Island, 64 on San Juan Island, 20 on Lopez Island, 18 on Shaw Island, and 6 on Blakely Island with an estimated total 158 miles. Only a few of these streams are naturally accessible to anadromous salmonids as the vast majority enter the marine environment from points that are naturally perched or enter at a gradient too steep for anadromous salmonid access. There are no known naturally sustaining populations of anadromous or resident salmonids in the freshwater habitats of WRIA 2.

The Habitat Limiting Factors Report

As a first step in the long-term commitment to salmonid recovery in Water Resource Inventory Area 2 (WRIA 2), representatives from the Washington Conservation Commission and the WRIA 2 Technical Committee worked together to develop this Habitat Limiting Factors Report. The purpose of this report is to provide a current "snapshot in time" of the existing salmonid species and habitat conditions that limit the natural production of salmonids in the San Juan Islands. This area is collectively termed WRIA 2 for the purposes of this report.

This report:

- Provides a summary of what is known about current and past salmonid species and habitat conditions in the WRIA for future reference;
- Provides baseline information for the WRIA (based on currently available data) for use in the implementation of an adaptive management program;
- Identifies limiting habitat factors in the WRIA, key findings, and associated data gaps; and
- Provides guidance for policy makers to determine next steps and direct resources for the recovery process.

Focus on Limiting Habitat Factors

While the causes of declining salmonid populations can be attributed to many factors, this report focuses on human-controlled modification or destruction of saltwater nearshore habitats and the changes to ecological processes that effect those habitats in WRIA 2. This approach was selected because of the geographic location of the San Juan Islands and their importance as a nursery ground for juvenile and sub-adult salmonids on their migration routes from their natal streams to the Pacific Ocean and their return.

The nearshore marine habitats in WRIA 2 are diverse and include marine riparian vegetation, banks and bluffs, beach and backshore, tidal marshes, tidal flats, eelgrass meadows, kelp forests, and water column habitats. These habitats act together to create the productive marine ecosystem of the San Juan Islands by providing the physical, chemical and biological processes that form habitats and drive critical functions.
Historic maps of nearshore marine and estuarine habitats are lacking in WRIA 2 and only recently have comprehensive mapping efforts (WDNR Washington State ShoreZone Inventory) been undertaken that attempt to adequately assess the region's nearshore marine resources. Overwater structures, shoreline armoring, climate change, resource exploitation, contamination, have all contributed to losses of habitat area and their functions in the region. There is no comprehensive understanding of the effects of multiple stressors on the viability of nearshore marine habitats in the region.

Value of the San Juan Islands (WRIA 2) to Salmonids

There are no known naturally reproducing salmonid populations and/or stocks in the San Juan Islands. The value of the San Juan Islands is the diverse nearshore habitats that serve as nursery grounds to migrating juvenile salmonids from other watersheds and in their production of forage fish utilized by sub-adult and adult salmon on return migrations.

Forage fish found within or expected in the nearshore marine habitats of WRIA 2 include herring, surf smelt, and Pacific sand lance. Within WRIA 2, there are numerous known herring spawning areas and a number of documented surf smelt and Pacific sand lance spawning beaches. Continuing studies are documenting additional forage fish spawning areas.

WATERSHED OVERVIEW

Physical Description

Out of the more than 170 islands that comprise this archipelago, lying at the juncture of the straits of Georgia and Juan de Fuca, and sheltered from the Pacific Ocean by the Olympic Peninsula and Vancouver Island along with an estimated additional 300 rocky "islands" at low tide there are four major islands. The San Juan Islands were once part of a mountain range connecting Washington to Vancouver Island. Eighty-three islands are protected as part of the San Juan Wildlife Refuge.

The are four islands served by the Washington State Ferry service – Lopez, Orcas, San Juan, and Shaw and the majority of the permanent and transient population resides on these islands. About 40 of the other islands have either permanent or temporary residents. Within WRIA 2, there are numerous smaller watersheds but this report focuses on the nearshore marine habitats.

Fish Status

Chinook, sockeye, coho, kokanee, steelhead, rainbow and coastal cutthroat trout as well as native char (Bull trout), and one non-native salmonid (Atlantic salmon) have been recently found in the marine waters of the San Juan Islands. Additionally, at least 4 non-native fish species (Eastern brook trout, large-mouth bass, yellow perch and kokanee) have been introduced into the freshwater lakes in WRIA 2.

Marine Nearshore

Primary designated land uses: agricultural, residential, land preservation

Recently documented salmonid species present: The streams of WRIA 2 offer only limited opportunities for natural production of salmonids. However, all species of juvenile and adult salmonids from other WRIAs and salmonid prey items such as herring, sandlance, and surf smelt have been observed in the marine nearshore waters of WRIA 2.

The Marine Nearshore (Nearshore) is, by definition those habitats that lie between the lower limit of the photic zone (approximately at minus 30 meters MLLW) and the upland–aquatic interface. This zone provides a critical link in the life history of all anadromous salmonids for physiological transition, feeding, refuge and as a migration route to and from the ocean. Most anadromous salmonid species utilize the Nearshore for juvenile rearing.

The overwhelming majority of the marine shoreline of WRIA 2 is still intact with its linked processes and functions. Berry (1997) estimated only 20% of the marine shorelines of the San Juan Islands and eastern Strait of Juan de Fuca had been modified. This is in contrast to the more "developed shorelines of WRIA 8 where 87% of the shoreline has been modified (Kerwin 2001).

All migratory juvenile anadromous salmonids are dependent on healthy and functioning nearshore environments. Nearshore habitats produce important prey items for anadromous salmonids including vertebrate and invertebrate species utilized by juveniles and forage fish (e.g.: herring, sandlance, and surf smelt) utilized by subadult and adult salmonids.

There are solutions to all of the problems outlined in this report. Riparian buffers can be reestablished that meet the needs of salmonids and then the vegetation allowed to mature.

The Habitat Limiting Factors Report is a step toward salmonid recovery in WRIA 2 and other Puget Sound WRIAs. The information presented in this report is a start. As new information is brought forward or is developed any conservation and recovery effort should be modified as necessary.

What This Report is Not

This report should be considered a work-in-progress. It does <u>not</u> examine the roles of hydropower, hatcheries or harvest management. These other "H's" are inextricably linked to salmon recovery in Pacific Northwest.

PURPOSE OF REPORT

The successful recovery of naturally spawning salmon populations depends upon directing actions simultaneously at harvest, hatcheries, habitat and hydro, the 4H's.

The 1998 and 1999 state legislative sessions produced a number of bills aimed at salmon recovery. Engrossed Substitute House Bill (ESHB) 2496 is a key piece of the 1998 Legislature's salmon recovery effort. While both habitat protection and restoration need to be a part of the state's overall salmon recovery strategy, the focus of ESHB 2496 is primarily directed at salmon habitat restoration.

ESHB 2496 in part:

- directed the Conservation Commission in consultation with local government and the tribes to invite private, federal, state, tribal and local government personnel with appropriate expertise to act as a technical advisory group (TAG);

- directed the TAG to identify limiting factors for salmonids to respond to the limiting factors relating to habitat pursuant to section 8 sub 2 of this act;

- defines limiting factors as "…conditions that limit the ability of habitat to fully sustain populations of salmon."

- defines salmon as all members of the family salmonidae which are capable of self-sustaining, natural production.

The overall goal of the Conservation Commission's limiting factors project is to identify habitat factors limiting production of salmon in the state. In waters shared by salmon, steelhead and bull trout we will include all three. Later, we will add bull trout only waters.

It is important to note that the responsibilities given to the Conservation Commission in ESHB 2496 do not constitute a full limiting factors analysis. The hatchery, hydro and harvest segments of identifying limiting factors are being dealt with in other forums.

SESSB 5595 is a key piece of the salmon recovery effort from the 1999 Legislature's 1st Special Session. This legislation reaffirmed the needs to complete a limiting factors report (as found in 2496) and among other items modified the definition of limiting factors to mean "… conditions that limit the ability of habitat to fully sustain populations of salmon ..." While striking out that portion of the definition found in ESHB 2496 dealing with barriers, degraded estuarine areas, riparian corridors, stream channels and wetlands. Removing those terms does not eliminate them from inclusion in the limiting factors report, rather it expands the scope of the report to include those elements for inclusion along with other pertinent elements specific to the WRIA in this report.

WATER RESOURCE AREA DESCRIPTION

The San Juan Islands (WRIA 2) (Islands) are group of 175 islands located to the east of Victoria, British Columbia, west of Anacortes and north of Puget Sound. The Islands have approximately 117,846 acres of land of which 10,036 acres are within 200 feet of the shoreline. Lying in the rainshadow created by the mountains on the Olympic peninsula and Vancouver Island, they have the smallest landmass of any county in Washington and the longest shoreline of any county in the United States. Collectively the Islands contain over 90 freshwater streams with a total length of approximately 100 miles.

No more than a dozen of these streams are believed to offer anadromous fish access and information concerning their usage by anadromous salmonids is scarce. The vast majority have natural blockages that occur where they enter saltwater. While we detail the known distribution of anadromous and resident salmonids in freshwater habitats in Appendix A, the overwhelming significance to anadromous salmonids are the marine and nearshore habitats of the Islands. These nursery grounds are utilized by an unknown number of anadromous salmon stocks from both the United States and Canada and are rich in the production of forage fish such as herring, sand lance and surf smelt, all of which are prey species utilized by chinook and coho salmon.

HISTORIC STATUS OF SALMONID POPULATIONS IN THE SAN JUAN ISLANDS (WRIA 2)

Virtually no historic information concerning the presence of anadromous salmonids in the freshwater environments of WRIA 2 was located during the course of preparing this report. In one portion of the Washington Department of Fisheries Stream Catalog (Williams et al 1975) there is an indication that adult coho had been observed in streams 02.0019 and 02.0027 on San Juan Island. They also indicated adult coho salmon utilization in the lower 0.5 miles of Cascade Creek on Orcas Island (02.0057). However, elsewhere in that same report salmonid utilization in Cascade Creek is listed as “Unknown”. An adult chum carcass was observed in an unnamed independent tributary (02.0027) and chum and pink salmon fry were observed in saltwater at the mouth of 02.0057 (Castle pers comm). A watershed characterization report (San Juan County 2000) reported that long- term island residents recount that most of the larger island streams supported fish runs in the “recent past”. While no species was indicated, included in these later anecdotal reports were salmon observations in the creeks 02.0027, 02.0047, 02.0057, an unnamed and unnumbered stream that drains from Hummel Lake to Swifts Bay on Lopez Island, and the creek that drains Crow Valley into West Sound on Orcas Island (02.0072).

Anadromous coastal cutthroat trout have been reported in streams 02.0072, 02.0066, 02.0066, 02.0057 (Johnston pers. comm.).

A salmon hatchery, currently operated by the non-profit organization *Long Live the Kings*, has been in operation in the East Sound area of Orcas Island since 1978. The hatchery initially reared and released approximately 150,000 Samish River stock fall chinook annually. Coho juveniles were initially reared and released as yearling smolts in 1997 and young of the year chum salmon juveniles were first released in 1999. Adult salmon return to a tidewater trap where they are held and spawned. Juvenile salmon are reared in spring water upstream of the trap and released in the vicinity of Giffin Rocks.

Resident trout are found in a number of lakes throughout the San Juan Islands but none are believed to be self-sustaining. The known distribution of anadromous and resident salmonids and some warmwater fish species is shown in Appendix A.

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FEATURES OF THE SAN JUAN ISLANDS

Geology and Hydrology

There are two distinct types of geologic landforms that are known to occur in the San Juans. The first consists of bedrock domes thinly covered with late Quaternary (glacial) sediments commonly found on San Juan, Shaw, and Cypress (which is in Skagit County) Islands. The second type is composed of bedrock buried beneath sediments more than 300 feet thick in places and is found on Lopez, Waldron, and Decatur Islands. However, neither geologic formation is exclusive to any individual island. Portions of Orcas, Lopez, and Waldron have surface exposures of bedrock, and parts of Orcas and San Juan have thick glacial deposits (White 1994).

Bedrock Geology (Pre-Quaternary)

Bedrock geology dominates the landscape of the San Juan Islands. Surface elevations range from sea level up to 2,454 feet at the summit of Mt. Constitution on Orcas Island. The highest point on San Juan Island is Mt. Dallas (1,036 feet), on Lopez Island it is Lopez Hill (535 feet), on Shaw Island it is Ben Nevis Hill (385 feet), and on Blakely Island it is Blakely Peak (1,042 feet).

Prior to the onset of the glaciation, this region of the coastline was augmented by micro-continents traveling eastward along the Juan de Fuca plate. As these much smaller landmasses impacted the main North American continent, they were accreted onto the coastline. The resulting structural geology described by Brandon (1988) is a complex combination of overlapping thrust faults along tectonic lenses and plates.

Glacial History (Quaternary)

During the last ice age 10,000 – 14,000 years ago, the advance and retreat of glaciers shaped the bedrock and developed the landscape of the islands. The entire region was scoured by a blanket of ice as deep as several thousand feet which carved out marine channels.

As the glaciers advanced from north to south and then retreated in the opposite direction they created numerous bays and waterways throughout the San Juan Islands. The higher elevations of bedrock were carved, scraped, and rounded. When the glaciers retreated, a layer of debris was left behind, covering the low-lying areas with unconsolidated glacial deposits that included clay, silt, sand, gravel, and boulders.

In the San Juan Islands, glacial and interglacial deposits are relatively thin when compared to other areas in Puget Sound where this type of deposition may be several thousand feet thick. Contour maps of sediment thickness generated from well logs kept by San Juan County show most of the San Juan Islands to have less than 20 feet of sediment cover (White 1994). The thickness of glacial deposits, compared to the other glacial layers left during the same glacial period in other parts of the Puget Lowland, is miniscule. The thickness of glacial sediments and their distribution in the San Juan Islands varies greatly, with large pockets scattered at random in low-lying areas and little or no sediment found elsewhere. The two largest concentrations of sediment are located on Lopez and Orcas Islands, where portions extend below sea level.

Hydrology

Approximately 10,000 years ago, during the last melting of the glaciers, became supercharged cracks in the bedrock formations of the San Juan Islands with groundwater. All the available underground spaces were filled as meltwater percolated as deeply as possible into cracks, pores, and pockets within the bedrock. Today, all this groundwater recharge comes from rainfall. The San Juan Islands do not have the major surface water river systems common on the mainland and elevations are not sufficient to have any snow pack upon which to rely for fresh water.

Because the San Juan Islands are dependent on rainfall to supply domestic needs and maintain physical and biological functions, it is important to understand how the hydrologic cycle works in the islands.

Hydrology is the study of the character, distribution, movement and effects of the earth's water. The conditions of climate, topography, geology, soils and vegetation are interacting elements in the hydrologic cycle.

There is a common misconception in the San Juan Islands that fresh groundwater comes from Mt. Baker and the Cascades. This is not possible due to the structural complexity previously mentioned. As well, the hydraulic head of a well is directly proportional to the elevation of the source of the groundwater. This relationship holds true no matter how far the groundwater travels from its original source.

Under natural conditions, precipitation either runs off the land into larger bodies of water (runoff), is used by plants and evaporates into the atmosphere (evapotranspiration), or enters ground water and is stored (recharge). All of these components influence the yield and distribution of water within a watershed.

Runoff

The amount of runoff varies throughout the San Juan Islands depending on size of the drainage basin, slope gradient, depth of soil, type and condition of vegetation, and precipitation. The larger the amount of runoff, the higher the potential for erosion and subsequent nonpoint pollution due to sedimentation.

Proceeding from south to north in the San Juan Islands, annual runoff estimates for an undeveloped landscape at sea level varies from a low of 3 inches to a high of over 8 inches. Runoff also increases with increasing precipitation at higher elevations, up to 13 inches on Mount Constitution.

Runoff throughout the San Juan Islands is low for lands in Western Washington, due to the rain shadow effect of the Olympic Mountains, small drainage basins, and the presence of coarse, porous glacial sediments over bedrock. However, runoff is high proportionally, due to the presence of bedrock and impervious soil layers. The highest periods of runoff occur mostly from December through March when soils are saturated and rainfall is heaviest. Runoff estimates developed using the runoff modeling program indicate that 28 percent of average annual precipitation is not captured and becomes runoff. This amount can vary from 11 percent to 45 percent depending on the impact of evapotranspiration combined with variations in rainfall. The False Bay watershed has the greatest volume of runoff for any basin in the San Juan Islands with 3,154 acre-feet per year. The next largest volume of runoff is for the Crow Valley basin, with 2,276 acre-feet. The largest drainage on Lopez drains to Davis Bay with a volume of 743 acre-feet (EES 1990).

Land Use

Prior to Euro-American settlement, the San Juan Islands were occupied by central coast Salish tribes. The Songhees, Saanich, Lummi and Samish tribes all had winter villages in the southern Gulf and San Juan Islands and more permanent structures were constructed for other seasons. During summer and early fall months the populations commonly traveled to other locations where resources were seasonally available.

Euro-American settlement began in earnest in the 1850's, first with the establishment of a fish salting station at Salmon Banks on the southern tip of San Juan Island by the Hudson's Bay Company. With the passage of the Land Claims Act in 1850 encouraging settlement throughout the Pacific Northwest additional Euro-American settlement was encouraged and an agricultural station called the Bellevue Farm was established in 1853. By the 1890's settlers had spread from San Juan Island to Lopez, Shaw, Orcas, Decatur and Blakely Islands and started small subsistence farms and raising livestock.

Extensive logging during the late 1890's and early portion of the 20th Century removed most of the valuable old growth timber on the islands. Significant deposits of lime were found on San Juan Island and the processing of this resource also consumed large amounts of wood to run the lime kilns and for barrel making. Large sandstone quarries were located on Waldron, Stuart and Sucia Islands.

As of 2000, the San Juan Islands had 210 miles of paved and 71 miles of dirt county roads covering approximately 1295 acres. No estimate of private roads was located during the course of this investigation.

Land use within the Islands is primarily agriculture followed by low density single family residential, commercial and infrastructure support. Residential development tends to be concentrated along shorelines and in upland areas with views.

Population

According to the year 2000 Census the population of San Juan County is 14,077. This represents a population increase of approximately 80 percent in the last 20 years.

These numbers do not include the increase in population during the summer tourist season. Seasonal increases from visitors and part-time residents are believed to be three to four times the year round resident population and are detailed in Table 1 below. For example, during January 2000 the average daily count for the Washington State Ferry route from Anacortes to the San Juan Islands was 1101. During August 2000, on the same route the average daily passenger count was 4043. Airplanes, private ferries, private boats and commercial tour boats account for additional seasonal visitors to the islands. Additionally, currently a minimum of two private ferry companies transport people seasonally to the San Juan Islands. Their combined capacity is approximately 149 passengers and they operate at or near capacity during the month of August.

Table 1: A seasonal comparison of Washington State Ferry riders for the San Juan Islands

Route	Average Daily Passenger Count for January 2000*	Average Daily Passenger Count for August 2000*	Increase in Number of riders/percentage
Anacortes to Lopez Island	546	1244	698 / 227 %
Anacortes to Shaw Island	53	162	109 / 305 %
Anacortes to Orcas Island	837	2880	2043 / 344 %
Anacortes to San Juan Island	1101	4043	2942 / 367 %
Totals	2537	8329	5792 / 328 %

* Data from Washington State Ferries

The Washington State Office of Financial Management (OFM) predicts that San Juan County will grow in resident population between one and 1.5 percent annually between 2000 and 2010. However, during the time period from April 1, 1990 to April 1, 2000 population within San Jan County grew by 26.56 percent with an average annual increase of 3.4%.

NEARSHORE FEATURES OF THE SAN JUAN ISLANDS

The outline for this chapter is adapted from Williams et al (2001), and relies largely on information contained in the Washington State Department of Natural Resources (WDNR) ShoreZone database (WDNR 2001).

Oceanography and Physical Processes

Regional Setting

In the Pacific Northwest, Puget Sound is the southernmost of a series of interconnected, glacially scoured channels that include the Strait of Juan de Fuca and Strait of Georgia in Canada. The entrance to the Sound is about 135 km from the Pacific Ocean. Glaciers have repeatedly occupied the Puget Lowland. There have been at least three, and possibly as many as six, episodes of glaciation that have rearranged the landscape and left evidence of their passage in the rocks and sedimentary record. The most recent glaciation, called the Fraser, extended as far south as Olympia. At its maximum extent 14,000 to 15,000 years ago, the ice sheet was about 7,000 feet thick at the border between the United States and Canada (49^{th} Parallel) where it tapered to about 4,000 feet at Port Townsend. The Puget Lobe of the most recent glacier created the north-south fabric of the topography and deposited in its wake the Vashon Till that currently blankets much of the region.

The San Juan Islands lie to the north of Puget Sound and as the glaciers advanced from north to south they created the intricate network of bays and waterways, including the San Juan Channel, West, East and Lopez Sounds. The bedrock of the Islands was shaped as the glaciers advanced and retreated. As the glaciers retreated they left behind debris that blanketed most of the Puget Sound lowlands but is relatively thin in the Islands. Maps of sediment thickness generated from well logs show most of the Islands have less than 20 feet of sediment cover (White 1994). Glacial sediment thickness is inconsistent between the islands and even on single islands. The two thickest concentrations of glacial sediments are located on Lopez and Orcas Islands where they extend below sea level.

Tides and Sea Level

The tides in the San Juan Islands are mixed-semidiurnal (i.e., two high and two low tides each lunar day with unequal amplitude). The tidal range is generally constant among the islands from less than 3 meters to more than 5 meters. The tidal flow enters the Islands from the Strait of Juan de Fuca (from the west and south) and Strait of Georgia (from the north).

Sea level is gradually changing in the Puget Sound region. The isostatic (rebound) adjustment after the retreat of the last glacial maximum is no longer believed to be important to sea level changes in this region. The mean continental adjustment is associated with the crustal subduction and underthrusting of the oceanic and continental plates off the coast. Near Seattle, the crust is subsiding as much as 2mm/year while on Vancouver Island the land is emerging at a rate of 1 to 3 mm/year. Combined with the observed sea level rise of about 1 mm/year, the land around the southern end of Puget Sound is sinking at an annual mean rate of 2 to 3 mm/year while that on much of Vancouver Island is rising at an annual mean rate of 1 to 2 mm/year. This scenario does not take into account the possibly rapid and catastrophic readjustment that may follow a major earthquake (Newton et al. 1997).

Wind Patterns

The winds around the San Juan Islands do show a significant sea breeze effect as is evident in the Strait of Juan de Fuca and along the open coast (Coomes et al. 1984). The topography adjacent to the San Juan Islands constrains the wind within channels, which are primarily oriented north-south. From October through March the flow is predominantly from the south-southwest. Through the spring, this flow gradually reverses direction until it is predominantly from the north during much of the summer season.

Waves

Wave conditions in the San Juan Islands are considered generally mild even though storm winds are occasionally severe. Waves are locally generated, and height and period are limited by fetch and somewhat limited by the narrow channels.

Most wave studies have been conducted on a project basis and may involve a short measurement period coupled with wave estimates based on wind conditions and accounting for orographic effects and bottom refraction.

Sources of Sediments

Sources of beach sediments are scarce throughout the Islands. Freshwater drainage basins are small, some only a few acres in size, and are dependent on rainfall for flow. Because the Islands lack the large river systems found on the mainland that are responsible for sediment transport from upstream reaches, sandy beaches are naturally scarce. However, that scarcity makes the mud and sand beaches all that more valuable. Wave action is responsible for moving sediments off the rocky shores and into the few protected bays.

Drift Cells

A drift cell, also called a littoral cell, is a partially compartmentalized zone along the coast that acts as a closed or nearly closed system with respect to transport of beach sediment. In other words, drift cells are systems in which sediment is suspended by waves or currents and transported along the shoreline in a repetitious cycle of suspension and deposition. The direction of the transport of sediment is determined by the dominant direction of the waves and currents in that cell. Although wave and current direction varies frequently, over time each cell shows a direction of net transport.

Drift cells are important because they are the mechanism that supplies nearshore environments with the majority of the sediments they require. Drift cells nourish beaches, provide fine sediments to flats, and maintain sand spits and other coastal landforms.

SELECTED NEARSHORE HABITAT TYPES

There are numerous habitat types that occur within the nearshore environment, including eelgrass meadows, kelp forests, flats, tidal marshes, subestuaries, sand spits, beaches and backshore, banks and bluffs, and marine riparian vegetation. These habitats are responsible for providing a myriad of critical biological functions. For example, eelgrass meadows, kelp forests, flats, tidal marshes, sand spits and riparian zones provide primary production. All of the habitat types also provide a supportive role to invertebrates and juvenile and adult fishes (including juvenile salmonids), and provide foraging and refuge opportunities for birds and other wildlife.

There are several known factors which cause stress to these habitats, including physical disturbances from shoreline armoring, marina construction, and bivalve harvesting; shading from overwater structures; contamination by chemicals; and competition from non-native species. Unfortunately, there exist numerous data gaps in our understanding of these habitats which make it difficult to fully assess them. In many instances information about the historical distribution/abundance of these habitats is lacking, and there are no comprehensive maps. What role these habitats play in the food web is also not well understood, as are the effects of shoreline armoring and bivalve harvesting.

This chapter provides additional detail about the functions of, stressors to, and data gaps about these nearshore environments. Where known, it also discusses the current and historic distributions of these habitats in WRIA 2.

Eelgrass

Functions within Ecosystem

Eelgrass (*Zostera marina* L.) is one of five known species of seagrass that occurs in the Pacific Northwest. It can be found as individual plants, small patches or large meadows in the low intertidal and shallow subtidal zone in the Islands. Sometimes referred to as “eelgrass beds” the more accurate term is “eelgrass meadows” which we will use in this report. Phillips (1984) listed the following functions for eelgrass in the Pacific Northwest:

- primary production;
- nutrient processing;
- wave and current energy buffering;
- organic matter input;
- habitat for fish and invertebrates; and
- nesting material and food for birds.

There is a growing understanding of the importance of eelgrass meadows in the nearshore habitats. Much of what we know about eelgrass comes from studies of primary production in the Pacific Northwest, including Puget Sound, that indicate eelgrass productivity can equal, and in some instances, exceed the productivity rates of most other aquatic plants.

Rates reported for eelgrass productivity in the Pacific Northwest range from 200-806 g C m^{-2} yr^{-1} (Thom 1984, Kentula and McIntire 1986, Thom 1990).

Eelgrass is not a seaweed; it is a blooming underwater grass which spreads by rhizomes or roots. Eelgrass meadows build up in the spring and summer, then decay in the fall and winter. Eelgrass plants prefer soft bottom tideflats such as muddy or sandy substrates and can not anchor themselves to rocks.

Each blade of an eelgrass plant can be characterized as a small food factory. Diatoms, bacteria, and detritus (decaying plant and animal matter) gathers on eelgrass leaves. This detritus provides food for a wide number of marine invertebrates; isopods, amphipods, polychaete worms, brittle stars, and some clams. The large number of invertebrates present make eelgrass beds rich feeding areas for fish and marine birds. As eelgrass dies, bacteria and fungi feed on the dead leaves, breaking them down into tiny bits. These particles of plant material provide vital nutrients for the nearshore food web.

Eelgrass plants produce organic carbon that can enter the food web through the microbial decomposition and processing of both particulate and dissolved eelgrass materials. followed the flux of particulate organic matter throughout an eelgrass system in nearby Padilla Bay. Fish, including juvenile and subadult salmonids, and marine mammals can then incorporated this organic matter in their diets (Simenstad et al. 1988). Large mats of eelgrass originating from very dense eelgrass meadows accumulate high on beaches, where they are broken down by bacteria and macroinvertebrates important in the diet of fish and birds. The ability of eelgrass to alter sediment composition and dynamics has not been studied in the Pacific Northwest, but it is believed that the meadows do affect sediment deposition. It has been found that eelgrass increases the organic matter in sediments in Puget Sound. Eelgrass mediates nutrient fluxes into and out of the sediment (Thom et al. 1994a).

Limited data show that once eelgrass is established in an area, there is an increase in fish and shellfish using the area (Thom et al. 1999). In Drayton Harbor, there is a clear indication that juvenile chum and chinook salmon use eelgrass for feeding and rearing during spring. Herring are known to lay eggs on eelgrass. Simenstad (1991) listed other fish that use eelgrass habitat for refuge or feeding areas including: the bay pipefish; crescent gunnel; kelp perch; lingcod; penpoint gunnel; shiner perch; snake prickleback; striped seaperch; and tube-snout. Numerous species of birds are associated with eelgrass habitat and they feed on the plants, invertebrates, and fish found associated with the eelgrass meadows. These birds include the black brant, bufflehead, Canada goose, common snipe, glaucus-winged gull, great blue heron, greater yellowlegs, night heron, common cormorant, and spotted and least sandpipers. Dungeness crab, Pacific harbor seals, river otters (Simenstad et al. 1991b) and red rock crab are also associated with eelgrass meadows. Among the few direct grazers on eelgrass plants are the black brant goose and isopods (*Idotea resecata*) (Thom et al. 1995). A rich epiphytic flora and associated small invertebrate fauna form seasonally on eelgrass leaves. Eelgrass meadows provide a multitude of functions including habitat structure, refuge, prey resources, and reproduction.

Damage to eelgrass affects whole populations of fish, including threatened salmon, waterfowl, shellfish, and other animals, as well as the stability of our shorelines.

Ecological Processes that Maintain Eelgrass Meadows

Eelgrass meadows commonly occur in shallow soft-bottom tideflats, along channels, and in the shallow subtidal fringe. Factors that affect its distribution and growth along with the ranges that are optimal for eelgrass are shown in Table 2.

Table 2: Factors controlling eelgrass growth

Factor	Optimal Conditions
Light	3 M PAR d^{-1}; spring and summer
Temperature	7-13 ^oC
Salinity	10-13$^o/_{oo}$
Substrata	Fine sand to mud
Nutrient	Soil nutrients present moderate to low water column
Water Motion	Up to 3-m s^{-1} tidal 80-cm s^{-1} burst. Some motion is good

Source: Thom et al. (1988); unpublished data; Phillips (1984).

Location of Eelgrass

Eelgrass occurs from about +1 ft. to –22 ft. MLLW in the San Juan Islands (Thom et al. 1995.). The primary factor controlling distribution at the upper boundary is desiccation stress, and at the lower boundary is light penetration (Thom et al. 1998). Competition for light and nutrients with macroalgae species can also affect eelgrass distribution.

Our current understanding of the distribution of eelgrass is limited because comprehensive surveys have not been performed within the Islands (WRIA 2). The primary sources of distribution data are from surveys that included observations made during low tides and covered primarily intertidal and very shallow subtidal meadows and patches. These data include the Coastal Zone Atlas (Washington Department of Ecology 1979), which is more than 20 years old, and very recent estimates provided by the Washington State Department of Natural Resources (1999).

WRIA 2 Eelgrass Distribution

The amount of eelgrass along selected island shorelines in WRIA 2 is shown in Table 3.

Table 3: Linear amounts of Eelgrass along selected shorelines in WRIA 2

(Source: WDNR 2001)

	Eelgrass (*Zostera spp*.)(feet)	
Island Name	**continuous**	**patchy**
Blakely Island	14,362.35	4,346.29
Crane Island	3,786.22	8,578.03
Decatur Island	20,027.23	9,574.63
Henry Island	14,997.24	22,780.75
Lopez Island	97,620.76	89,544.06
Orcas Island	69,957.57	8,3505
San Juan Island	54,347.15	92,589.29
Shaw Island	39,080.01	63,630.59
Stuart Island	869.99	18,863.52
Sucia Island	13,490.77	14,835.13
Waldron Island	33,270.12	5,660.87

Eelgrass Density

Eelgrass density is highly variable but Thom et al (1998) found densities in excess of 800 shoots m^{-2} in central Puget Sound. However, no reports on density of eelgrass in WRIA 2 were located during the course of this investigation. Mean densities that have been reported from specific studies range from about 50-400 shoots m^{-2} (Thom 1988, Thom and Hallum 1989); (Thom 1990, Thom and Albright 1990)).

Stressors

Stressors to eelgrass plants are those things that negatively affect the factors that control eelgrass growth or directly affect eelgrass itself. There are two broad categories of stressors: natural stressors, and human-influenced stressors. The following section discusses each in turn.

<u>Natural Stressors</u>

Natural stressors to eelgrass include the following:

- Increased turbidity
- Foraging
- Black rot disease
- Rhizome exposure
- Hydrogen sulfide in soils

Suspended sediments or phytoplankton blooms can reduce water clarity through increased turbidity. A persistent reduction in water clarity would result in less light reaching the eelgrass plants, and could cause eelgrass, especially those plants at the lower (deeper) edge of the distribution, to die and/or become stressed and succumb to another stressor.

Black rot disease was responsible for killing almost all eelgrass on the eastern United States in the 1930s (many East Coast eelgrass populations have since recovered and are now considered healthy). Black rot disease has been recorded and confirmed for Puget Sound, but systematic surveys for the disease are not available for WRIA 2 (Bulthuis 1994).

Waves and currents can expose eelgrass rhizomes. The extended exposure, especially during low tides, can result in damage to the plants because of desiccation of the roots and rhizomes. However, there is no documentation of excessive exposed rhizomes in WRIA 2.

Hydrogen sulfide (H_2S) develops in highly organic sediments. Eelgrass is susceptible to high H_2S levels and will die if H_2S is a persistent feature of the sediment conditions (Goodman et al. 1995). There are no documented cases of loss of eelgrass due to high hydrogen sulfide levels in WRIA 2.

Human-Influenced Stressors

Stressors to eelgrass caused or exacerbated by human activities include the following:

- shellfish harvesting;
- propeller scour and wash;
- eutrophication;
- physical disturbances from shoreline armoring;
- shading from overwater structures; and
- physical disturbances from dredging and filling.

In the study region, clam harvesting on Orcas and San Juan Island beaches has been observed to disturb the benthic community, (Kerwin pers obs) at least temporarily. However, no systematic quantification of this effect has been attempted. The physical disturbance by excessive propeller wash can gouge sections of eelgrass meadows. These gouges are commonly observed in heavily used beaches, especially where shellfish harvesting is popular. However, no cases of this problem are documented in WRIA 2.

Eutrophication has been shown to result in the growth of massive amount of epiphytes on eelgrass leaves, which can result in the death of the eelgrass host. There is little information on epiphyte loads in the region.

Eutrophication in Puget Sound is believed to influence the buildup of massive ulvoid mats that grow in the intertidal and shallow subtidal zones. Ulvoids detach during windy periods, and pile up in thick mats over eelgrass, which can smother and kill the eelgrass (Thom et al. 1998). There was no information discovered during the course of this investigation that indicated eutrophication was a problem in WRIA 2.

Shoreline armoring (e.g.: riprap, bulkheads) impedes the supply of sediments to nearshore habitats, and this sediment starvation can lead to changes in the geographic size, particle size and composition of nearshore substrates. However, shoreline armoring along the shorelines of the San Juan Island is of less concern because of the area's natural rocky shorelines. Sediments typically are found in sheltered bays where currents are not able to sweep sediments into deeper waters. Typically, sediment changes from sand or mud to coarse sand, gravel, and finally hardpan. If sediment becomes too coarse, eelgrass may be driven out. Also, construction of shoreline armoring devices can cover or destroy eelgrass meadows (Williams and Thom, in prep.). Overwater structures can deprive eelgrass meadows of the light they need to thrive (Fresh 1995; Simenstad et al., 1998). Dredging operations can excavate eelgrass meadows or cause detrimental increases in turbidity, and filling can smother eelgrass meadows permanently.

The numbers of boat ramps, marinas, docks and piers in WRIA 2 are shown in Table 4 below.

Table 4: Locations, types and numbers of overwater structures and boat ramps in the San Juan Islands (Source: WDNR 2001)

Island Name	Number of Boat Ramps	Number of Pier and Docks	Number of Small Slips	Number of Large Slips
Blakely Island	5	6	98	1
Crane Island	0	7	29	0
Decatur Island	1	10	29	0
Henry Island	0	24	58	0
Lopez Island	8	42	267	2
Orcas Island	16	112	797	5
San Juan Island	5	148	1078	1
Shaw Island	4	25	71	1
Stuart Island	3	12	58	4
Sucia Island	1	2	15	0
Waldron Island	1	2	4	0

Historic Distribution

Comprehensive historic records of eelgrass distribution are lacking in WRIA 2. Eelgrass information comes from site-specific studies, which are incomplete in terms of providing a historical picture of distribution.

Thom and Hallum (1990) compiled all known records of eelgrass meadows in an attempt to document changes in eelgrass. The oldest records came from marks on U.S. Coast and Geodetic Survey navigation charts that were developed for several bays in Puget Sound, including Padilla Bay. These charts date back in some cases to the period of 1850-1890. No records on these charts showed eelgrass in any portion of WRIA 2. A copy of these charts is attached in Appendix D and other similar charts can be viewed at: http://anchor.ncd.noaa.gov/states/wa.htm.

Reasons for Change

We surmise that eelgrass meadows occurred in most shallow water areas with suitable substrate in the San Juan Islands, and that disturbances such as overwater structures, bulkheads, marinas, and dredging and filling have resulted in loss of eelgrass in the region. Areas where intertidal eelgrass may have declined (e.g.: Friday Harbor) are in regions of extensive shoreline armoring and overwater structures. However, the few mapping records located were conducted at different scales and with various methods, making it difficult to draw any scientifically defensible conclusions.

Data Gaps

Gaps in our knowledge of eelgrass within WRIA 2 include the effects of shoreline armoring and shellfish harvest on eelgrass meadows. The WDNR ShoreZone (2001) database provides reach specific information on shallow eelgrass distribution but does not reach to deeper waters. We also do not know enough about the historic distribution and abundance of eelgrass to draw any scientifically meaningful conclusions. Monitoring of eelgrass beds eventually would show trends in density and abundance, and perhaps allow scientists to distinguish natural variability from adverse effects of human activities. Better data on fish use of eelgrass, and the effects of urban runoff on eelgrass, would contribute to improved management efforts.

Table 5: Data gaps for eelgrass

Gaps
Complete maps, including measurements of area
Monitoring of eelgrass beds
Incidence, causes, and effects of ulvoid blooms
Effects of nutrient loading and urban runoff on eelgrass
Anoxic sediment impacts
Shellfish harvesting impacts and recovery rates
Effects of shoreline hardening
Interannual variability and natural vs. human-influenced controls of variability
Fish (especially juvenile salmon) and invertebrate use

Kelp

Kelp Functions within the Ecosystem.

Bull kelp, *Nereocystis luetkeana* (Mertens) P. & R., is the largest and fastest growing brown algae in the world. It can grow from a tiny spore into a 200-foot long plant in one summer. By winter, the kelp plants are dying. Storm caused waves and winds leave them on the beach, where they appear as brown "bull whips". Bull kelp goes by a number of colorful names including; Bull whip kelp, ribbon kelp, bulb kelp, giant kelp, sea kelp, horsetail kelp, and sea otter's cabbage.

Bull kelp forms small patches to large forests in the shallow subtidal zone of the San Juan Islands. The other large brown algal species common in the study region include, *Laminaria saccharina*. *S. muticum* is a non-native species that was introduced by the Japanese (Pacific) oyster mariculture industry to the Northwest in the 1930s (Anderson 1998).

There is no comprehensive evaluation of the functions of kelp in Puget Sound, but the following list highlights functions typically associated with kelp:

- primary production;
- habitat for fish, especially rockfish, but also salmon;
- contributor to pelagic food webs through particulate and dissolved carbon;
- herring spawning substrate;
- wave and current buffering (Duggins 1980)H(Harrold et al. 1988), (Jackson and Winant 1983));
- substrate for secondary production; and
- extraction of chemicals for commercial use (Whyte and Englar 1980).

A bull kelp forest provides a large three-dimensional habitat. This is important for many fish whose larvae use the kelp as settlement habitat. Adult and sub-adult fish, including chinook salmon feed on and hide in the kelp fronds of the San Juan Islands (Kerwin pers obs). Many invertebrates such as crabs, snails, bryozoans, sponges, tunicates, anemones, and shrimp use the blades as living habitat (Foster and Schiel 1985).

Primary production has been estimated as growth rates in only a few areas in the Pacific Northwest. Bull kelp can grow at rates up to approximately 2 feet per day during the spring and early summer. Growth rates of other kelp species are slower than bull kelp (Thom 1978).

Processes that Maintain Kelp

Kelp grows attached to bedrock or pebble to larger sized gravel in the very low intertidal and shallow subtidal zone. It has been demonstrated that kelp growth is dependent on light and temperature (Rigg 1917, Vadas 1972, Druehl and Hsiao 1977). Limited experimental evidence indicates that *N. luetkeana* photosynthesis is limited by carbon during summer

(Thom 1996). Because of this, all of the kelps exhibit a dynamic seasonal cycle with a period of maximum growth rate in spring and early summer. Winter is a period of low biomass. The stipe and fronds of bull kelp die completely in winter, and exists as a microscopic phase until spring. None of the kelps are resistant to drying. Hence, plants that colonize the intertidal zone early in spring are generally lost to desiccation later in spring. Because it forms a dense canopy, bull kelp can exhibit major control over the abundance of the other kelp and algal species attempting to colonize beneath a bull kelp forest (Thom 1978).

Kelp plants are subject to consumption by grazing sea urchins, which generally feed on drift material, but sometimes removing entire plants by grazing through their holdfasts (Foster and Schiel 1985). Some gastropods graze on the plant tissue, but do not remove entire kelp plants.

Variations in the amount of rocky substrata can result in gains and losses of kelp. Landslides can affect early spring development of kelp through excess siltation (Shaffer and Parks 1994).

Location and Distribution of Kelp

Kelp occurs in small to large meadows throughout WRIA 2. Maps are available for *Nereocystis luetkeana* and *Laminaria saccharina* and are located in Appendix B.

<u>Linear Distance of Kelp in WRIA 2</u>

The amount of shoreline in which *S. muticum*, *Nereocystis spp*, and *Laminaria spp* are present is shown in Tables 6, 7, and 8 below.

Table 6: Linear amounts of *Sargassum muticum* along selected shorelines in WRIA 2. (Source: WDNR 2001)

	Sargassum muticum		
Island Name	**Shore Length (feet)**	**Continuous**	**Patchy**
Blakely Island	67,879	5,715	29,319
Crane Island	16,310	0	14,669
Decatur Island	67,053	4,984	17,545
Henry Island	61,490	0	28,688
Lopez Island	366,111	7,957	113,935
Orcas Island	434,556	46,937	215,649
San Juan Island	407,033	0	77,666
Shaw Island	140,683	0	85,366
Stuart Island	81,565	1,575	47,917
Sucia Island	74,976	2,535	50,819
Waldron Island	61,519	0	43,664

Table 7: Linear amounts of *Laminaria spp.* along selected shorelines in WRIA 2. (Source: WDNR 2001)

Island Name	Soft-brown Kelp (*Laminaria spp.)*		
	Shore Length (feet)	**Continuous**	**Patchy**
Blakely Island	67,879	2,140	31,889
Crane Island	16,310	0	14,669
Decatur Island	67,053	14,328	25,574
Henry Island	61,490	2,621	35,475
Lopez Island	366,111	37,872	130,649
Orcas Island	434,556	29,565	210,436
San Juan Island	407,033	9,067	185,468
Shaw Island	140,683	1,368	111,354
Stuart Island	81,565	10,803	60,834
Sucia Island	74,976	0	52,903
Waldron Island	61,519	0	39,853

Table 8: Linear amounts of Bull kelp (Nereocystis spp.) along selected shorelines in WRIA 2. (Source: WDNR 2001)

Island Name	Bull Kelp (*Nereocystis spp.*)		
	Shore Length (ft)	**Continuous**	**Patchy**
Blakely Island	67,879	2,309	19,934
Crane Island	16,310	0	5,175
Decatur Island	67,053	0	11,829
Henry Island	61,490	7,310	9,666
Lopez Island	366,111	29,423	33,664
Orcas Island	434,556	33,116	52,641
San Juan Island	407,033	56,874	62,429
Shaw Island	140,683	1,188	22,726
Stuart Island	81,565	22,022	21,649
Sucia Island	74,976	744	28,533
Waldron Island	61,519	4,556	16,604

Stressors

There are no investigations on the overall health or indicators of health for kelp in the San Juan Islands. Some potential health indicators are:

- Degree of tissue bleaching;
- Epiphyte loads;
- Changes in distribution and density;
- Physical disturbances from shoreline armoring, marina construction, and harvesting; and
- Shading from overwater structures.

Spilled petrochemicals can cause bleaching of kelp tissue, which results in death of the plant (Antrim et al. 1995). Epiphytes normally occupy kelp plants (Markham 1969, Thom 1978). Where abrasion has damaged the epidermal tissue, infection by epiphytes appears to be more pronounced (Thom 1978). Heavy epiphytic loads have been noted in some Puget Sound locations. Although not known, this type of damage may affect the growth and survival of the plant.

Nutrient loading can adversely affect kelp growth. While outside the area of this report, Thom (1978) found that brown algal cover was negatively related to increasing sewage volume at Seattle beaches. Shading from overwater structures in Elliott Bay has also been observed (Thom, personal observations contained in Williams et al in prep) as a potential stressor.

There are also unknown stressors to kelp. For example, the kelp bed north of Protection Island National Wildlife Refuge near Port Townsend, WA. began decreasing from 181 acres in 1989 until it completely disappeared in 1997. Anthropogenic impacts to Protection Island are thought to be minimal because it is approximately 4 kilometers offshore and of its status as a wildlife refuge. The cause of the disappearance of the kelp beds around Protection Island is not known.

Historical Distribution of Kelp

It is likely that kelp distribution has changed little in the study area based on maps produced by the Department of Agriculture in 1911-1912 and maps produced for the Coastal Zone Atlas in the mid-1970s.

Reasons for Change

WDNR monitoring of kelp forests along the Strait of Juan de Fuca indicates that kelp forest abundance and distribution changes annually to some degree. Year to year variation of 30 percent is common (Bookheim, pers. comm. contained in Williams et al 2001). Annual variability, driven by natural factors (e.g.: climate), probably occurs in the waters of the San Juan Islands as well.

Data Gaps

The general lack of historic and recent studies of kelp in the San Juan Islands results in numerous gaps in our knowledge. Mapping distribution and monitoring over time, studies of kelp forest ecosystems and species interactions, and the impacts of development and changes in water chemistry would prove invaluable for enhancing our understanding and improvement of our management of kelp and kelp dependent species. Some of the most critical data gaps in our knowledge of kelp include:

- complete maps of kelp forest area;
- monitoring of kelp forests;
- interannual variability and natural vs. human-influenced controls of variability;

- harvest impacts;
- effects of shoreline hardening;
- ecological tradeoffs of kelp forest expansion due to shoreline armoring;
- fish (especially juvenile salmon) and invertebrate use;
- role of nutrients, temperature, and chemical contaminants on kelp growth and health;
- effects of anthropogenic discharges on kelp; and
- effects of *Sargassum muticum* competition in disturbed kelp forests.

Flats

Functions within Ecosystem

Flats can be variously defined, but generally encompass gently sloping sandy or muddy intertidal or shallow subtidal areas. Using criteria developed by Simenstad et al (1991), mudflats consist of unconsolidated sediment with particles that are smaller than stones and are predominantly silt (0.0625 to 0.00391 mm) and clay (0.00391 to 0.00024 mm)(Simenstad et al. 1991b). The substrate is typically high in organic content with anaerobic conditions existing below the surface. Sandflats have unconsolidated sediment with particles that are smaller than stones and are predominantly sand (2.0 to 0.074 mm) (Simenstad et al. 1991b). The substrata on flats can also be composed of a mixture of pebbles and cobble. There is no comprehensive assessment of the functions of flats in the Pacific Northwest. Studies conducted in Puget Sound and other Washington estuaries have proven the following list of functions for flats:

- primary production;
- nutrient cycling;
- habitat/support for juvenile and adult fish;
- shellfish production;
- prey production for juvenile salmon, flat fish, and shorebirds;
- detritus sink;
- predator protection for sand lance; and
- wave dissipation for saltmarsh

There is commonly a dense flora of microalgae, primarily diatoms, which inhabit the fine sediments of flats. The concentration of Chlorophyll ‘a’, an indicator of the density of microalgae, is reported to range from 140-380 mg m^{-2} on flats in Puget Sound (Thom 1989). Published rates of primary production measured for flats range from 22-59 g C m^{-2} $year^{-1}$ (Thom 1984, Thom 1989). The flux rates of inorganic nutrients can be substantial on flats, especially muddy flats (Thom et al. 1994a). Flats that have more organic matter and higher densities of benthic infaunal invertebrates tend to have higher respiration rates and associated nutrient flux rates. Nutrient flux from flats may be an important source of nutrients to primary producers in the general vicinity of the flats, although this has not been conclusively shown.

Juvenile salmon prey species have been shown to be seasonally abundant on flats and their distribution is linked to the benthic microalgal abundance (Thom et al. 1989).

Undisturbed channels and sloughs within tidal flats contain numerous invertebrates and fish and are used by shorebirds, herons, raccoons, otter, mink, and other organisms as important foraging areas. Precise invertebrate assemblages probably vary with salinity and substratum type, but common animals include chironomid (insect) larvae, amphipods, polychaetes, clams, shorecrabs, tanaids, and mysids (Dethier 1990).

Fish species that feed on invertebrates from flats include chum salmon, bay goby, Pacific staghorn sculpin, English sole, sand sole, speckled sanddab, and starry flounder (Simenstad et al. 1991b).

Especially in flats containing some gravel, shellfish densities can be substantial (Armstrong et al. 1976, Thom et al. 1994a). In some instances, gravel has been purposely added to flats to enhance clam production for commercial and recreational harvesting.

Shorebirds are commonly observed feeding on flats in the Pacific Northwest. Studies in Grays Harbor (Herman and Bulger 1981) and Padilla Bay indicate that the birds are consuming invertebrates produced on the flats. American Widgeon preferentially consumes the non-native seagrass *Zostera japonica*. Other birds that feed on flats include the bufflehead, common goldeneye, horned grebe, common snipe, dunlin, great blue heron, and the least and western sandpipers (Simenstad et al. 1991b).

Processes that Maintain Flats

In the San Juan Islands, the sediment required to maintain flats is primarily supplied by streams. Nearshore currents and waves, along with stream flow dynamics, act in concert to distribute and rework sediments on flats. While sediment composition as well as sediment dynamics exert primary control over the biological community that develops on flats, seasonal abundance of algae and invertebrate prey species also appears to be driven by variations in light and temperature (Thom et al. 1989). In addition, detritus sources help maintain levels of organic matter that are an important component of flats and support biotic communities that utilize flats.

Location of Flats

In the San Juan Islands, flats are generally located in sheltered bays and at the mouths of streams where sediment transported downstream is deposited. They are also located in embayments, below the swash/backwash zone and other areas of low wave and current energies where longshore currents and waves deposit sediment. The location of and estimates of the linear feet of tidal flats can be obtained from the ShoreZone database (WDNR 2001). The ShoreZone definition of flats is unidirectional, horizontal, or gently sloping surfaces of less than 5°. This definition, or the resolution of mapping methods, likely does not capture all flats in the study area.

Sediment Characteristics of Flats

Flats generally include gently sloping sandy or muddy beaches, but can also include a mixture of pebbles and cobble. No information was located during the course of this investigation that provided sediment grain size data from flats in WRIA 2.

Stressors

There are no comprehensive studies on the health of flats in WRIA 2. Health indicators include, but are not limited to, the following:

- Unnatural erosion or deposition of sediment;
- Harvesting of shellfish and other marine life;
- Overabundance of organic matter loading including ulvoid mats;
- Fecal and chemical contamination;
- Physical disturbances from shoreline armoring, marina construction, and upland development practices;
- Shading from overwater structures;
- Competition from non-native species; and
- Loss of emergent and riparian vegetation

Several of these indicators are suspected of occurring throughout WRIA 2.

Historic Distribution

There are no maps of the distribution of flats other than what can be deduced from Coast and Geodetic Survey nautical charts developed in the mid-to-late 1800s. These charts are available for larger deltaic flats such as the Skagit, Nooksack, and Duwamish River deltas, but are not available for the nearshore areas and smaller stream deltas found in the San Juan Islands. The linked bathymetry-topography maps developed by the University of Washington's Puget Sound Regional Synthesis Model (PRISM) (http://www.prism.washington.edu/indexh.html) are based on records from the mid-1950s and later. Based on these maps, flats occur in most embayments.

Reasons for Change

Changes have occurred and are generally the result of focal points of road construction and residential development mainly in sheltered bays. However, lacking historic data it was not within the scope of this project to quantify the amount of change.

Data Gaps

The total impact on juvenile salmonids and other estuarine resident species is not well understood in WRIA 2. The following are the identified data gaps for flats in WRIA 2

- complete maps of flat area;
- interannual variability and natural vs. human influenced controls of variability;

- role of flat production in the food web;
- shellfish harvest impacts;
- effects of shoreline hardening;
- fish and invertebrate utilization; and
- the role of nutrients, temperature and chemical contaminants on benthic plant and animal growth and health.

Tidal Marshes

Functions within Ecosystem

Tidal marshes include both salt and freshwater marsh habitats that experience tidal inundation. The general functions of tidal marshes include those commonly listed for wetlands, which include: fish and wildlife support; groundwater recharge; nutrient cycling; flood attenuation; and water quality improvement. Studies conducted in Puget Sound and other Washington estuaries have proven the following list of functions for tidal marshes:

- primary production;
- juvenile fish and invertebrate production support;
- adult fish and invertebrate foraging;
- salmonid osmoregulation and overwintering habitat;
- water quality;
- bird foraging, nesting, and reproduction;
- wildlife habitat;
- detrital food chain production; and
- wave buffering

Primary production rates for regional tidal marshes range from 529-1,108 g C m^{-2} yr^{-1} (Thom 1981). Juvenile salmonids have been demonstrated to reside in tidal marshes in the Nisqually River estuary, the Puyallup River estuary and Grays Harbor. Salmon forage on prey resources produced in, and imported to, the marsh system (Shreffler et al. 1992). Significant growth of juvenile salmonids residing in these systems has also been reported. Prey resource production has been documented in small, restored tidal marshes in the Duwamish Estuary (Simenstad and Cordell 2000). Subadult or adult salmon have been reported in Spencer Spit Saltmarsh (Lakey pers comm).

Processes that Maintain Tidal Marshes

Tidal marshes accrete sediment and organic matter and thereby build land both upward and outward. They are primarily maintained through adequate hydrology and sediment supply. Tidal marshes generally occur in the more protected areas where waves and currents can not significantly erode the substrates. Salinity effects saltmarsh plant species composition and the lower limits of their distribution. In addition, surface (river and stream channel) and groundwater (seepage) discharge influence salinity, thereby influencing plant species composition and distribution. Alterations to hydrology, sediment supply, sea level, or marsh plant production can affect the maintenance of the marsh.

Location of Tidal Marshes

The WDNR ShoreZone (2001) database provides locations for the tidal marshes in WRIA 2. We were unable to field verify the location of all of the tidal marshes in WRIA 2.

High marsh plants include *Carex lyngbyei*, *Distichlis spicata*, *Juncus balticus*, and the non-native *Phragmites* sp.

Table 9: Linear amounts of mixed and low marsh habitats along selected shorelines in WRIA 2 (Source: WDNR 2001)

	Mix Marsh (TRI/SAL/Desh)(feet)		Low Marsh (*Salicornia*)(feet)	
Island Name	**Continuous**	**Patchy**	**Continuous**	**Patchy**
Blakely Island	0	0	0	2,239
Crane Island	0	0	0	0
Decatur Island	1,776	0	1,133	3,334
Henry Island	6,580	0	5,066	5,600
Lopez Island	10,330	31,662	31,627	23,139
Orcas Island	1,971	5,033	3,956	6,048
San Juan Island	6,544	23,543	8,638	48,013
Shaw Island	0	4,578	2,302	11,509
Stuart Island	0	737	0	1,678
Sucia Island	1,193	2,028	697	3,379
Waldron Island	0	0	0	0

Stressors

There have been no reports on health indicators of tidal marshes in the region. Some potential health indicators are as follows:

- disturbed community structure;
- disturbed plant growth;
- presence of non-native species;
- buffer encroachment;
- runoff scour;
- elevated soil contaminant concentrations;
- presence of man-made debris;
- physical disturbances from shoreline armoring, marina construction, and harvesting; and
- chemical contamination.

These systems are vulnerable to physical disturbances by anthropogenic actions (i.e., filling, dredging, hydrologic constriction, boat wakes) as well as chemical contamination. Debris, such as plastics and other anthropogenic materials, can accumulate in tidal marshes, which can bury and smother marsh plants (Thom et al. 2000). Cordell et al. (1998) found that some of the small emergent wetland patches were frequently disturbed by wave action, large pieces of industrial and woody debris, and boat wakes. The study also observed that grazing by geese might be limiting emergent growth in some areas.

Historic Distribution

The historic distribution of tidal marsh habitat in the San Juan Islands prior to settlement is unknown. These areas were likely vegetated by *S. maritimus* and *S. americanus*, *C. lyngbyei*, and *Triglochin maritimum*. Vegetation found higher in the marsh probably included tufted hairgrass (*Deschampsia caepitosa*), saltgrass (*Distichlis spicata*), pickleweed (*Salicornia virginica*), Baltic rush (*Juncus balticus*), silverweed (*Potentilla pacifica*), and red fescue (*Festuca rubra*) (Dethier 1990).

Reasons for Change

A review of aerial photographs of the shorelines of the San Juan Islands taken by the Washington Department of Ecology between 1992 and 1997 indicates several instances where historic salt marsh habitat has been cut off from the marine environment. Roads along the shoreline and filling appear to be responsible for this loss.

Data Gaps

The total impact on juvenile anadromous salmonids and other estuarine resident species is not well understood. Significant data gaps in marsh ecology, such as the extent of interannual variability, role of upland buffers in marsh migration, and interactions between marshes and riparian zones, also exist. The significance of marshes in groundwater recharge, the role of periodic disturbance in marsh ecology, and the importance of large woody debris as habitat structure in marshes also are not well studied. Table 10 lists the identified data gaps.

Table 10: Data gaps for tidal marshes

Data Gaps
Complete maps of marsh area
Interannual variability and natural vs. human-influenced controls of variability
Role of reduced or altered upland buffers in allowing marshes to migrate inland with sea level rise
Role of marsh production in the food web
Fish (especially juvenile salmon) and invertebrate use
Interactions between marshes and riparian zones
Role of marshes in groundwater recharge
Role of periodic disturbance in marsh ecology
Role of large woody debris as habitat in marshes
Carrying capacity of disturbed and undisturbed marshes
Role of nutrients, temperature, and chemical contaminants on benthic plant and animal growth and health

Sand Spits

Functions within Ecosystem

Sand spits may enclose (partially or totally) intertidal estuarine areas. Substrata are typically sand, silty sand, or gravelly sand. Functions of sand spits in the San Juan Islands include:

- Foraging areas for waterfowl and shorebirds;
- Prey production for shellfish, marine fishes, and macroinvertebrates;
- Infauna production (i.e., bivalves, burrowing worms);
- Primary production; and
- Spawning habitat for forage fishes

In general, pickleweed *(Salicornia virginica)* dominates the upper zones of these estuarine, intertidal marsh areas, forming dense mats. Other halophytes such as *Distichlis spicata* and *Atriplex patula* may be present (Dethier 1990).

Processes that Maintain Sand Spits

In the Pacific Northwest, sediment particles contributing to sand spit formation originate primarily from fluvial, rather than marine, sources (Simenstad et al. 1991b). However, in the San Juan Islands, sediments deposited on sand spits may also originate from eroding bluffs. Waves and currents transport this material along the shoreline until it settles out near an embayment, forming a spit. Changes in river sediment load, ocean currents, and wave action can affect the maintenance of sand spits.

Location of Sand Spits

The current distribution of sand spits in WRIA 2 is extremely limited. The ShoreZone database (WDNR) does not include spits. However, documentation of shore-drift patterns indicates that several small spits do exist (Washington Department of Ecology 1991).

Stressors

These systems are vulnerable to filling, dredging, boat wakes, and changes in sedimentation rates such as those caused by shoreline armoring. They also are vulnerable to physical disturbances caused by shoreline development.

Fecal coliform and pathogen contamination can occur on sand spits but no evidence of such an event was located for the San Juan Islands during the course of this investigation. Chemical contamination is unlikely in WRIA 2, but few studies have focused on sand spits.

There have been no reports of health indicators specific to sand spits in the region. However, general health indicators that have been reported, or can be assumed to effect areas that contain sand spits include the following:

- Unnatural erosion or deposition of sediment;

- Fecal and chemical contamination;
- Alteration of natural habitats; and
- Overharvesting of shellfish

Historic Distribution

Very little information is available on the historic distribution of sand spits in WRIA 2.

Reasons for Change

Shoreline armoring, shoreline development, dredging, and filling are likely the major causes for loss of sand spits and associated habitat.

Data Gaps

Little current and historical information on sand spits is available for WRIA 2, and we do not know conclusively how natural and anthropogenic forces affect them. Table 11 shows gaps in our knowledge of sand spits, including their role in the food web and as habitat for fish and invertebrates.

Table 11: Data gaps for sand spits

Gaps
Natural interannual variability vs. human-influenced controls of variability
Role of sand spit production in the food web
Fish, invertebrate, and wildlife use of existing spits
Cumulative and site-specific effects of shoreline armoring and other development practices on spits
Carrying capacity of disturbed and undisturbed spits

Beaches and Backshore

Functions within Ecosystem

Beaches include boulder, cobble, gravel, sand, and silt areas and they comprise only a small portion of the shorelines of the San Juan Islands. Generally, they are steeper than tideflats described above. Backshore areas are immediately landward of beaches and are zones inundated only by storm-driven tides. The intertidal portion of the beach, between OHW and about MLW, is typically relatively steep and comprised of a mixture of cobbles and gravel in a sand matrix. At about MLW the beach slope typically breaks to a relatively flat low-tide sand terrace.

Functions supported by beaches are numerous, and are generally similar to those described above for tideflats. However, the level of each function differs from tideflats. Ecological functions of beaches that have been documented in the region include:

- Primary production
- Nutrient cycling

- Refuge for multiple species
- Prey production for juvenile salmon and other marine fishes
- Fish habitat, including forage fish spawning
- Infaunal and epifaunal production

Organisms in these habitats are diverse, with both epifauna and infauna. Beaches are used as feeding areas by juvenile and subadult cutthroat trout, juvenile salmon, piscivorous birds such as cormorants, grebes, loons, mergansers, and great blue herons, bivalve-eating birds such as scoters and goldeneye (Dethier 1990), and shorebirds that probe into the substrate, or sweep the shallow water with their bills for invertebrate prey.

The ecological functions of backshore areas have not been thoroughly studied. However, we do know that woody debris (large and small) accumulates in this zone through transport at extreme high tides and during storm events. It is generally assumed that this woody debris aids in the stabilization of the shoreline, traps sediments and organic matter, and provides microhabitats for invertebrates and birds. Backshore areas also support a unique assemblage of vegetation tolerant of wind, salt spray, and shifting substrate.

Processes that Maintain Beaches and Backshore

Similar to tideflats, beaches and backshores are sustained by the ecosystem processes of erosion and deposition of sediments. Large woody debris and vegetation contribute to the formation and maintenance of beaches and backshore areas.

Location of Beaches and Backshore

As previously mentioned, beaches and backshore areas occur within only limited reaches of WRIA 2. A beach is an accumulation of unconsolidated material formed by waves and wave-induced currents in the zone that extends landward from the lower low water line for large (spring) tides, to a place where there is a marked change in material or physiographic form, usually the effective limit of storm waves. Backshore areas are those where water reaches only during extreme high tides that occur during major storms.

The ShoreZone database (WDNR 2001) provides location and linear distances of beaches within WRIA 2.

Two taxa of seaweed, *Ulva* spp. and *Fucus gardneri*, dominate beaches in the region, but several other algal species may be locally common. *F. gardneri* (commonly referred to as rockweed) is always found attached to more stable rocks ranging from small cobbles to boulders or to artificial substrata such as pilings or riprap. *Ulva* (commonly referred to as sea lettuce) typically attaches to pebble or larger substrata, but may also be found in viable free-floating patches deposited along beaches. The distribution of rockweed provides a good indication of the general distribution of intertidal pebble-to-boulder substrata.

Stressors

Beaches are subject to the same stressors affecting flats. These include overabundance of ulvoids, physical disturbances as a result of shoreline armoring, contamination by organic matter and fecal coliform, *Spartina* conversion to monoculture marshes, and overwater structures and marinas. Shellfish harvesting can also be particularly damaging to these systems.

Some indicators of the health of beaches include the following:

- Fecal contamination;
- Chemical contamination;
- Alteration of natural habitats;
- Alteration of resource use of natural habitats;
- Alteration of sediment supply; and
- Presence of non-native species

Shoreline armoring is particularly harmful to recruitment of new beach materials. Because of the potential for fecal coliform and pathogen contamination, the beaches of WRIA 2 are monitored by the San Juan County Health and Community Services Department. Chemical contamination is unlikely, but few studies have focused on beaches.

Historic Distribution

No comprehensive historic maps are available for assessing the historic distribution of beaches. However, given the lack of substantial development that causes the destruction or alteration of beaches in the San Juan Islands, beach habitats are likely similar to historic levels.

Reasons for Change from Historic Distribution

Shoreline armoring, overwater structures, dredging, filling, and resource harvesting are likely the major causes for loss of beach habitat.

Data Gaps

WRIA 2 lacks the effect of massive urbanization that has taken place in many other mainland WRIAs. However, the cumulative effects of development on beaches and backshore are not well understood. Table 12 lists some of the gaps in our knowledge of beaches and backshore.

Table 12: Data gaps for beaches and backshore

Data Gaps
Role of production in the food web
Bivalve harvest impacts
Effects of shoreline hardening and other development practices
Fish (especially juvenile salmon and forage fish) and invertebrate use
Role of woody debris in nearshore ecosystem
Carrying capacity of degraded and undisturbed beaches and backshore areas

Banks and Bluffs

Functions within Ecosystem

Banks and bluffs are characterized as steep areas of varying heights, located between the intertidal zone and the upland. They are a portion of the riparian zone and act as an important transition area between the aquatic and terrestrial interface. The ShoreZone database (WDNR 2001) characterizes banks and bluffs as those areas with a slope of greater than 20 percent grade. Banks and bluffs can be composed of sediments of varying grain sizes as well as rocks and boulders. Functions performed by banks and bluffs include the following:

- Source of sediments to beaches
- Habitat for bluff-dwelling animals
- Support of marine riparian vegetation (and associated riparian functions)
- Source of groundwater seepage into estuarine and marine waters

Processes that Maintain Banks and Bluffs

These habitats are formed and maintained by the dynamics of numerous factors including their underlying geology, soils, wind, erosion, hydrology, and vegetative cover.

Location of Banks and Bluffs

Based on the ShoreZone database (WDNR 2001), the distribution of banks and bluffs of various types are shown in Table 13. As the table shows, bluffs in WRIA 2 are primarily high and steep.

Table 13: Shoreline lengths where various bank and bluff types were recorded in the ShoreZone database (WDNR 2001).

Type	WRIA 2 Length (m)	Percent of Total WRIA 2 Shoreline
Cliff –Total		
Inclined/low (20-35^o; <5m)		
Inclined/moderate (20-35^o; 5-10m)		
Inclined/high (20-35^o; >10m)		
Steep/low (>35^o; <5m)		
Steep/moderate (>35^o; 5-10m)		
Steep/high (>35^o; >35m)		

Stressors

The "health" of banks and bluffs is difficult to assess. Stressors include shoreline armoring, vegetative cover reduction, shoreline development, overwater structures, dredging, filling, sediment extraction, and hydrologic changes.

Residential development has caused some erosion and stability problems in a variety of places. In general a change in the erosion rate of these areas would affect not only the protection of the upland area, but also the sediment composition and elevation of beaches and other intertidal and shallow subtidal habitats. Hence, where bank erosion rates have been increased or where erosion has been interrupted by artificial means (i.e., a seawall), the health of the adjacent habitats that are dependent on sediment from the bluffs is affected. Additional information on these types of problems can be found in the Shoreline Conditions section of this report.

Historic Distribution

The historic distribution of banks and bluffs has not been mapped. Obvious, but unquantified, changes have occurred in areas where shoreline development has occurred.

Reasons for Change

The major obvious changes are likely due to shoreline armoring and coastal development that directly affects bluffs and their maintenance processes. For example, the bluffs behind and/or along shoreline associated roads were removed and/or lowered to form a pad for their construction.

Data Gaps

Within WRIA 2, only minor shoreline development and armoring activities have taken place over the last 125 years. However, the total impact this activity has on banks and bluffs is not well understood. Table 14 lists some of the data gaps in our knowledge of bluff and bank habitats in WRIA 2.

Table 14: Data gaps for banks and bluffs

Data Gaps
Incidence of drainage/stability problems on bluffs
Effects of shoreline armoring and other development on banks and bluffs
Portion of beach sediment budget contributed by bluffs
Groundwater input from bluffs and banks

Marine Riparian Zones

Functions within the Ecosystem

Riparian zones are best defined as those areas on or by land bordering a stream, lake, tidewater, or other body of water (Hall 1987) that constitute the interface between terrestrial and aquatic ecosystems (Swanson et al. 1982). They perform a series of vital functions that affect the quality of aquatic and terrestrial habitats as determined by their physical, chemical and biological characteristics. The interactions between riparian and aquatic zones are now recognized by scientists as so important that riparian buffers have been established as a central element of forest practice rules and watershed restoration efforts (Spence et al. 1996). Riparian vegetation composition, density and continuity are some of the most important characteristics of riparian systems. In general, healthy riparian systems have the following characteristics (Brennan and Culverwell, in prep.):

- Long linear shapes;
- High edge to area ratios;
- Microclimates distinct from those of adjacent uplands;
- Standing water present all or most of the year, or a capacity to retain water;
- Periodic flooding which results in greater natural diversity; and
- Composition of native vegetation differing somewhat from upland systems.

Most of what is known about riparian functions and values comes from investigations of freshwater systems, which have been the subject of extensive research. Although marine riparian zones have not been subject to the same level of scientific investigation, increasing evidence suggests that riparian zones serve similar functions regardless of the salinity of the water bodies they border (Desbonnet et al. 1994) and are likely to provide additional functions unique to nearshore systems (Brennan and Culverwell, in prep.). The riparian functions that are known, or likely to contribute to nearshore ecosystem health, include protection of water quality, and bank stability; provision of wildlife habitat, microclimate, and shade; and input of nutrients and large woody debris. Each of these functions is briefly reviewed below.

Water Quality

The use and effectiveness of vegetated buffers for pollution abatement and the protection of aquatic ecosystems has been well documented (Groffman et al. 1990; U.S. EPA 1993; Desbonnet et al., 1995; Lorance et al., 1997; Bernd-Cohen and Gordon 1998; Rein 1999; and, Wenger 1999). Vegetation binds similar and dissimilar soils, retains and absorbs contaminants, and reduces overland flow volume and velocity. The effectiveness of riparian buffers for pollution and sediment control depends on a number of factors, including (Brennan and Culverwell, in prep.):

- Soils;
- Geomorphology;
- Hydrology;

- Biological processes (i.e., microbial activity);
- Vegetation type;
- Slope height and angle;
- Annual rainfall;
- Level of pollution loading;
- Types of pollutants;
- Surrounding land uses; and
- Riparian buffer width.

Many of the contaminants introduced into the nearshore are passed through the food chain and are found in higher trophic levels. For example, Calambokidis (1995) and others have found excessively high levels of PCBs in harbor seals and orca whales in Puget Sound. Water quality is also a human health and safety issue. The beaches in the San Juan Islands are monitored for contaminants to ensure the safety of shellfish for consumption. Although this action is a good precautionary measure for human health and safety, much remains to be learned about direct and indirect cause and effect relationships between urbanization and the health of individual species and the ecosystem.

Wildlife Habitat

Healthy riparian areas along marine shorelines support abundant and diverse assemblages of wildlife. For example, Brennan and Culverwell (in prep.) identified 205 wildlife species (5 amphibians, 4 reptiles, 153 birds, and 43 mammals) in a review of wildlife species known or expected to have a direct association with riparian habitat along the marine shorelines in Central Puget Sound. The diversity and abundance of wildlife species is largely influenced by the composition and continuity of vegetation and the proximity of riparian areas to marine waters, which offers a moderate climate, greater habitat complexity and increased opportunities for feeding, foraging, cover and migration.

The habitat requirements of wildlife in freshwater riparian zones are complex and have received a significant amount of study and analysis. However, only a relatively few studies have focused on the habitat requirements of wildlife in marine riparian areas. Thus, we must depend upon wildlife studies and studies of riparian support functions from other areas to begin to understand the potential habitat requirements for wildlife of marine riparian areas. For example, Brown (1985) reports that 87 percent (359 of 414 species) of the species of wildlife in western Washington and western Oregon require riparian areas and wetlands during some season or part of their life cycle (Cedarholm et al., 2000). In their review of riparian buffers required to support wildlife in Washington State, Knutson and Naef (1997) determined that the average width reported to retain riparian functions for wildlife habitat was 287 feet. In their review of the literature on wildlife habitat protection, Desbonnet et al. (1995) offered recommendations of 198-330 feet for general wildlife habitat, 304 feet for protection of significant wildlife habitat, and 1980 feet for the protection of critical species. It is of special note that buffer requirements for freshwater systems may be significantly less than for some marine and estuarine riparian systems because of the influences of wind, salt spray, desiccation, and general microclimate effects on vegetation and associated wildlife.

Aside from direct habitat loss, one of the most significant impacts of urbanization on wildlife comes from habitat fragmentation (Stenberg et al. 1997; Knutson and Naef 1997). The isolation of remnant habitat parcels makes utilization and recolonization difficult or impossible (Knutson and Naef 1997). This is of particular concern for species with low mobility such as amphibians (Knutson and Naef 1997). Because many wildlife species depend upon wide, continuous corridors, vegetative cover, climate, food, and separation from the disturbance of urbanization, the loss and fragmentation that results from urbanization greatly limits wildlife species distribution, diversity and abundance. The development of a more thorough understanding of the life history requirements and their utilization of marine riparian zones, and the effects of habitat loss, alteration, and fragmentation for wildlife species will require additional directed studies in these areas.

Microclimate

The composition and abundance of riparian plant and animal communities are greatly influenced by their proximity to marine waters. Physical influences on these communities include:

- Temperature and moisture regulation;
- Tidal inundation;
- Wind exposure; and
- Salt spray.

The condition of riparian communities influences marine littoral communities, with overhanging vegetation and organic litter, moisture, and soils playing important roles in species distribution and abundance. Throughout both environments, numerous animal species, such as amphibians and upper intertidal invertebrates, depend upon the cool, moist conditions naturally found in these habitats for their survival. Many of the habitat-forming processes and much of the habitat complexity and structure is due to the presence of vegetation. Riparian vegetation provides shade and organic matter, retains soils and moisture, insect production as a prey item for juvenile salmonids, and reduces the effects of wind and salt spray.

When riparian vegetation is removed the result is increases in the exposure of the land and water to the sun, wind, and precipitation. The resultant impacts are increased temperatures, decreased moisture and humidity, increased runoff and elevated water temperatures entering marine systems, desiccation or erosion of soils, and increased stress for organisms dependent upon cool, moist conditions. As marine shorelines have become developed, some of these habitat features have been replaced with concrete, rock, and other impermeable structures that eliminate habitats and species from that location. It is assumed that the effects of alteration or elimination of microclimates in marine riparian areas as a result of urbanization are similar to the impacts that have been demonstrated in freshwater riparian areas. Further investigation is needed to quantify the relationship between marine riparian vegetation, microclimates and the impacts of urbanization.

Shade

The riparian vegetation along freshwater streams moderates the amount of solar radiation that reaches the stream channel and runoff entering the stream. This then results in a dampening of the seasonal and diel fluctuations in stream water temperatures (Beschta et al. 1987). In estuarine areas that receive tidal exchange and flushing of larger volumes of water, the effect of shading on water temperature would likely be substantially less than in small stream environments. Shade has long been recognized as an important factor in reducing desiccation from solar radiation in marine intertidal organisms (Connell 1972). In a literature review of the causes of spatial and temporal patterns in intertidal organisms, Foster et al. (1986) found that the most commonly reported factor responsible for setting the upper limits of intertidal animals is desiccation.

In the San Juan Islands and Puget Sound, there are few studies that show the direct linkage between shade and nearshore species composition, or dependence. However, Penttila (1978) suggests that shade can increase the success of surf smelt spawning by reducing the mortality attributed to thermal stress and desiccation. A recent study (Penttila, 2001) compared shaded and unshaded surf smelt summer spawning sites found that shaded sites had significantly lower egg mortality. Surf smelt are obligate beach spawners and are also an important source of prey for juvenile and sub-adult salmonids in the San Juan Islands and Puget Sound. Ongoing studies by investigators including the University of Washington may provide additional data that assists in a further understanding of the contribution of riparian vegetation in thermal regulation and species composition in supralittoral zones. However, additional information is needed to fully understand the importance of shading in the nearshore.

Nutrient Input

Riparian areas also serve as both sources of organic matter and sinks for trapping and regulating the flow of nutrients. Although the amount of input and level of importance to the marine system have not been quantified, riparian vegetation has the potential of producing significant amounts of organic matter. In a terrestrial ecosystem, the organic matter that falls to the forest floor and becomes a part of the soil, or enters the aquatic environment, directly or indirectly, contributes to the detrital food web. Organic detritus is the principal energy source for food webs in estuarine and shallow marine benthic portions of the ecosystem; the principal source of this detrital carbon is debris from macrophytes in the system (Gonor et al. 1988). Crowley (2000) tracked the flux of particulate organic matter throughout an eelgrass meadow in Padilla Bay and determined that eelgrass is a potential carbon sink and preferentially traps carbon rich resuspended sediments. Other important nutrients, such as nitrogen, are also fixed by roots of some plants and metered out to the aquatic system through runoff, leaf and stem litter, or large woody debris.

Riparian vegetation also makes indirect contributions of nutrients to the nearshore system in the form of prey resources, particularly for juvenile salmonids. The organic debris produced by riparian vegetation often collects on beaches and combines with marine-derived plant material to form beach “wrack”. The structure and decomposition of beach wrack attracts a complex and diverse array of terrestrial insects and marine invertebrates that act in concert to decay this material.

Many riparian plants attract and support the production of insects that become prey for terrestrial and aquatic consumers. A number of studies have identified terrestrial insects as a significant dietary component of juvenile chinook and chum salmon diets in subestuaries and other nearshore waters throughout Puget Sound (Fresh et al. 1979; Fresh et al. 1981; Pearce et al. 1982; Levings et al. 1991; Shreffler et al. 1992; Levings et al. 1995; Miller and Simenstad 1997; Cordell et al. 1999a,b). In addition, other aquatic based invertebrates, such as mysids and amphipods, are connected to vegetation via detritus-based food webs and serve as important prey for salmonids and other fishes, birds, and larger invertebrates in the nearshore.

Current nearshore food web analysis by the University of Washington has identified important habitats and food web connections for chinook salmon in Puget Sound, including:

- Intertidal and shallow subtidal areas that produce amphipods and other epibenthic crustaceans. As has been established for juvenile chum salmon, these probably include intertidal flats as well as vegetation and areas of high detritus buildup;
- Nearshore vegetated terrestrial habitats that are the source of terrestrial insects in the diets;
- Feeding on planktonic grazers such as euphausids, shrimp, and crab larvae, planktonic amphipods, and copepods; and
- Feeding on other secondary pelagic consumers such as herring and other fishes.

Only limited sampling and dietary analysis of juvenile salmonids and other species in the nearshore environment has been conducted and additional studies are needed to quantify and understand the contribution of riparian vegetation to nearshore food webs and the impacts of vegetation loss along marine shorelines. However, it is clear that as vegetation is eliminated, the food supply and thus the carrying capacity of the nearshore ecosystem is reduced (Brennan and Culverwell, in prep.).

Bank Stabilization

Marine associated riparian vegetation has been well documented as an effective tool in reducing erosion and increasing slope stability by intercepting and extracting moisture through the canopy and roots, mechanical reinforcement of soils and restraint by the roots and stems, and adding structure to beaches that traps sediments and protects the toe of slope (Macdonald and Witek 1994; Brennan and Culverwell, in prep.). Vegetation, once established, provides a self-perpetuating and increasingly effective permanent erosion control (Kittredge 1948; Menashe 1993). Soils, slope height and angle, drainage, and other factors are also very important in determining susceptibility to erosion. However, for all shorelines, and particularly those in areas with steep and eroding bluffs, native vegetation is typically the best (and most cost effective) tool for keeping the bluff intact and for minimizing erosion (Broadhurst 1998).

The loss or removal of shoreline vegetation can result in increased rates of erosion and higher frequency of slope failure. This cause-and-effect relationship can be demonstrated convincingly as a result of many field and laboratory studies reported in the technical literature. Land use practices, such as commercial and residential development, along with infrastructure such as roads, have all had an effect on the volume, type, density, and extent of riparian vegetation that remains along the shoreline. Removal for development, landscaping, and view corridors has largely been responsible for a decrease in the amount of vegetation available to perform slope stabilization functions. These activities also result in increased impervious surfaces. Combined, these alterations have resulted in increased erosion and, often, the subsequent installation of armoring, or bank stabilization structures, which typically results in additional vegetation removal. While many recommendations and efforts have been made to utilize vegetation management and alternatives to structural solutions for controlling shoreline erosion (see Macdonald and Witek 1994; Zelo et al. 2000), current regulations do not make use of these alternatives mandatory.

Large Woody Debris

One of the primary roles of riparian vegetation relative to aquatic ecosystems is the contribution of habitat structure in the form of large woody debris (LWD). The mechanisms for delivery of LWD into the nearshore include natural and human-induced erosion of banks and bluffs, erosion of wooded riverbanks and delivery through the estuary, and drift logs delivered by the tides. The role of LWD in freshwater lotic systems has been well documented and has led to increasing efforts to utilize LWD for bank stabilization and habitat restoration projects (Johnson and Stypula 1993; WDFW 1998). Coarse woody debris (CWD) is also an important component of estuarine and oceanic habitats (Gonor et al. 1988) and plays important roles for both fish and wildlife (Brennan and Culverwell, in prep.). Cedarholm et al. (2000) recognized the importance of LWD in increasing habitat complexity and heterogeneity, providing important benefits to salmonids in estuarine marshes and nearshore environments. Weitkamp (1982) observed juvenile salmonids feeding on biota attached to boom logs near Pier 90 in Elliott Bay. In Tillamook Bay, Oregon, large stumps have been placed on the mud flats at the mouth of the Tillamook River with the intent of increasing fish habitat (Tillamook Bay National Estuary Project 2000).

The presence of vegetation and woody debris (LWD and CWD) provides nutrients to the aquatic environment and refuge for fishes and wildlife, and function is as hydraulic buffers to flood and storm surges, or wave energies. Structurally, the presence of suitable amounts of LWD provides potential roosting, nesting, refuge, and foraging opportunities for wildlife; foraging, refuge, and spawning substrate for fishes; and foraging, refuge, spawning, and attachment substrate for aquatic invertebrates and plants in the nearshore environment (Brennan and Culverwell, in prep.). Logs that become imbedded in beaches serve to trap and sort sediments that assist in the construction and maintenance of berm and backshore habitats. The logs provide moisture and nutrients for the establishment of vegetation, which further stabilizes beaches. Once established, these features can be effective at reducing wave-induced erosion. In an effort to avoid the impacts of conventional shoreline armoring (bulkheads), a number of projects have selected alternatives that include the use of anchored logs and vegetation to decrease erosion (Zelo et al. 2000).

Location of Marine Riparian Vegetation

Marine riparian vegetation, defined as trees overhanging the intertidal zone, was estimated for unconsolidated shorelines at 636,570 feet of shoreline in WRIA 2 (WDNR 2001). This represents 25.7 percent of the shoreline. However, the width, species composition, continuity, density, and age structure of riparian vegetation has not been determined. These factors are important for determining riparian functions and values and for developing management and recovery options.

Stressors

Stressors can be broken down into natural and anthropogenic causes. Natural stressors include earthquakes, slides, disease, parasitism, wave action during storms, and wind. Anthropogenic stressors include vegetation clearing, increased impervious surfaces and surface water runoff, air and water pollution, herbicides, and intentional changes in vegetation (e.g.: landscaping). Vegetation removal and the introduction of exotic species change community structure, increase the chance of competitive interactions, change soil chemistry and microclimate, and increase solar and wind exposure.

Historic Distribution

Macdonald and Witek (1994) provide a brief historic description of vegetation type and distribution:

> *Historically, western Washington included the most densely forested region in the United States. Temperate coniferous forests predominated and the size and longevity of the dominant species was unrivaled elsewhere in the world* (Franklin and Dyrness 1988).
>
> *Explorers and early pioneers describe old-growth forest coming right down to the shore – an occurrence now limited to scattered inaccessible sites along the outer ocean coast of the Olympic Peninsula* (Egan 1990; Dunagan 1991; Kruckeberg 1991).

Historic photographs and other historical accounts of northwest estuaries (i.e., Sedell and Duval 1985; Maser et al. 1988; Dunagan 1991) suggest that the above description is representative of portions of the study area. Other areas had broad grasslands that sloped to either the shore or adjacent bluffs.

Reasons for Change

Vegetation clearing occurs with most development projects, including those at the water's edge. Timber from most of the San Juan Island's and Puget Sound shorelines was removed beginning around the turn of the 20th Century (Macdonald and Witek 1994). Timber on the shorelines was some of the first cut due to the ease of access and transport (Dunagan 1991) and for land development. Over time, vegetation has been removed for timber, housing and other land development, roads, view corridors, shoreline armoring, landscaping, beach access, and other land use practices. While a great amount of research, attention, and protection have been given to freshwater riparian areas, very little attention has focused on the potential importance of marine riparian areas. Some local governments provide limited guidelines for the removal of vegetation in their shoreline master programs, but most regulators admit it is extremely difficult to enforce (Broadhurst 1998) and regulations and enforcement have been woefully inadequate to protect this critical element of the nearshore ecosystem (Brennan and Culverwell, in prep.).

Data Gaps

Only limited amounts of research have been reported on marine riparian areas compared to freshwater systems. Limited amounts of research have occurred in other parts of the country on the effects of marine riparian vegetation on pollution abatement, soil stability, wildlife habitat, and fish habitat. However, little research has focused on Pacific Northwest systems. Additionally, regulations regarding functional buffer widths and riparian protection are not in place compared to freshwater systems. The functions and values of marine riparian vegetation need to be better documented in the scientific literature in order to provide a better understanding of riparian functions in marine ecosystems and to create adequate policies for protection and restoration.

Table 15: Data gaps for marine riparian zones

Data Gaps
Complete maps of marine riparian vegetation, including extent (width, continuity), type, density, composition
Percent impervious area and type of cover (i.e., concrete, asphalt, structures)
Role of MRZ in food web (contribution of organic carbon, insects, etc.)
Role of MRZ in providing water quality functions, especially non-point source pollution
Importance of MRZ in providing shade to fish & wildlife
Role of MRZ in providing microclimates
Role of MRZ in providing wildlife habitat
Role of MRZ in providing fish habitat
Role of MRZ in increasing slope stability
Cumulative impacts of shoreline armoring and other shoreline development and land use practices on MRZ and MRZ functions

Key Findings

- The nearshore marine habitats in WRIA 2 are diverse and include marine riparian vegetation, banks and bluffs, beach and backshore, tidal marshes, tidal flats, eelgrass meadows, kelp forests, and water column habitats.
- These habitats act together to create the productive marine ecosystem of the San Juan Islands by providing the physical, chemical and biological processes that form habitats and drive critical functions.
- Historic maps of nearshore marine and estuarine habitats are lacking in WRIA 2; only recently have comprehensive mapping efforts (WDNR Washington State ShoreZone Inventory) been undertaken that attempt to adequately assess the region's nearshore marine resources.

- Eelgrass productivity exceeds that of most other aquatic plants. Organic carbon produced by eelgrass is especially important in driving the nearshore marine food web of San Juan Islands.
- Overwater structures, shoreline armoring, climate change, resource exploitation, contamination, have all contributed to losses of habitat area and their functions in the region.
- Monitoring programs have not adequately addressed long-term changes in habitat distribution.
- There is no comprehensive understanding of the effects of multiple stressors on the viability of nearshore marine habitats in the region.

Eelgrass

- Eelgrass meadows are highly productive habitats that support primary production, process nutrients, provide wave and current energy buffering, supply organic matter, and provide invaluable fish and wildlife habitat.
- Stressors to eelgrass include natural factors such as disease and overgrazing, as well as human influences such as shoreline armoring, overwater structures, dredging, and filling.

Kelp Forests

- Kelp supports primary production, provides fish and wildlife habitat, contributes organic and particulate carbon to the food web, provides wave and current buffering, and is a substrate for secondary production.
- Stressors include nutrient loading and shading from overwater structures.

Flats

- Flats are invaluable habitats that support primary production, process nutrients, provide habitat for fish and wildlife, produce prey for fishes and shorebirds, and buffer wave and current energy.
- Stressors to flats include filling, dredging, overwater structures, and overharvest of flat plant and animal species.
- The health of flats is not clear.

Tidal Marshes

- Marshes support primary production, provide nursery areas for fish and invertebrates, produce prey resources for adult fish and invertebrates, support other wildlife, protect water quality, buffer waves, and shelter salmonids as they osmoregulate and overwinter.
- The distribution of marshes in WRIA 2 is extremely limited due to the natural features of the shorelines.

Sand Spits

- Sand spits provide foraging areas for wildlife, produce bivalves, and support primary production.
- Sand spits are vulnerable to filling, dredging, boat wakes, and changes in sedimentation rates such as those caused by shoreline armoring.

Beaches and Backshore

- Beaches and backshore areas support primary production, cycle nutrients, provide refuge for multiple species, produce prey for fishes, and support bivalves.

- Major threats to beaches include shoreline armoring, overwater structures, shellfish harvesting, and contamination with organic matter and bacteria.

Banks and Bluffs

- Bluffs provide sediments to beaches, habitat for wildlife, marine riparian vegetation, and groundwater seepage.
- Bluffs in WRIA 2 are primarily high and steep.
- Stressors include shoreline armoring, reduction of vegetative cover, shoreline development, overwater structures, dredging, filling, sediment extraction, and hydrology changes.

Marine Riparian Vegetation

- Very few data have been collected on the functions of riparian vegetation in estuarine and nearshore areas. However, marine riparian vegetation likely protects water quality, bank stability, microclimate, and shade; and provides wildlife habitat, nutrients and large woody debris.
- Stressors to marine riparian vegetation include earthquakes, landslides, storm waves, wind, clearing for development and landscaping, and shoreline armoring.

FORAGE FISH DISTRIBUTION AND USE

Forage fish, as their name implies, are a vital part of the prey base for marine mammals, sea birds, and predatory finfish populations in the San Juan Islands. Forage fish include a number of small, schooling species, and can serve as a valuable indicator of the health and productivity of our marine environment (Lemberg et al. 1997). In turn, they are reliant upon a variety of shallow nearshore and estuarine habitats (Table 16). In the San Juan Islands, forage fish include Pacific herring, surf smelt, and Pacific sand lance.

Table 16: An indication of nearshore and estuarine habitat use by forage fish.

Common Name	**Scientific Name**	**Nearshore and Estuarine Habitat Use**		
		Spawn	Adult Resid.	Juvenile Rear.
Pacific Herring	*Clupea harengus pallasi*	●	●	●
Surf Smelt	*Hypomesus pretiosus*	●	●	●
Sand Lance	*Ammodytes hexapterus*	●	Ukn.	Ukn.

Pacific Herring (*Clupea harengus pallasi*)

Pacific herring is the most widely known and best understood species of forage fish in Washington. Extensive research has been conducted on Pacific herring in Alaska and British Columbia and much of this research is applicable to Washington State herring stocks (Hay and McCarter, 1995).

<u>Juveniles</u>

After transformation from their larval form, juvenile Pacific herring usually stay in nearshore marine waters until fall. Sometime during early fall months they begin to disperse into deeper marine waters (Emmett et al. 1991). While in the nearshore marine waters they feed primarily on copepods and small crustacean larvae (Hart 1973)(Emmett et al. 1991).

<u>Adults</u>

Juvenile, subadult and adult Pacific herring do not make extensive coastal migrations, but rather move onshore and offshore in schools as they feed and spawn (Emmett et al. 1991). Adult Puget Sound herring stocks move onshore during winter and spring to holding areas prior to moving to inshore spawning grounds (O'Toole 1995), (Lemberg et al. 1997). Adult herring appear to consistently return to their natal spawning grounds, and, similar to anadromous salmonids, during spawning migrations herring may sharply reduce or stop feeding (Emmett et al. 1991), (Lemberg et al. 1997). The grounds utilized are very specific as is the time of spawning with the peak of spawning rarely varying more than 7 days year-to-year.

Most spawning in San Juan Islands occurs from late January through early April in lower intertidal and upper subtidal habitats, with most spawning between 0 and –3 m. Adhesive eggs are deposited upon firm substrates including eelgrass, algae, oyster shells, rocky-sandy bottoms, pilings, and driftwood (Lemberg et al. 1997). Juvenile Pacific herring in shallow nearshore habitats of the San Juan Islands feed primarily on copepods, decapod crab larvae, and chaetognaths (Fresh et al. 1981).

The location of bays where herring spawning activity has been found is illustrated in Figure 2 below. These include Westcott Bay on San Juan Island, West Sound and East Sound on Orcas Island, Blind Bay on Shaw Island, and Hunter Bay on Lopez Island.

Current Distribution and Use

At least 18 Pacific herring stocks, defined by spawning ground, occur inside Puget Sound with one additional stock occurring in coastal waters (Bargmann 1998). Pacific herring use the nearshore environment for feeding and spawning. Currently, there are two commercial herring fisheries in Washington; the principal one is in south-central Puget Sound and has annual average landings (1992-96) of 510 tons (Lemberg et al. 1997). Although Puget Sound herring stocks have declined over the past 20 years, the National Marine Fisheries Service decided they did not warrant listing under ESA in 2001. It is probable that Pacific herring of all ages pass through WRIA 2 nearshore habitats, especially as juveniles rearing during the summer months and as adults migrating to holding areas near natal spawning grounds. Figure 2 includes the distribution of documented herring spawning areas in WRIA 2. These data almost certainly are conservative because not all bays have been surveyed, and not all surveyed bays have been monitored in multiple years. Therefore, lack of documented spawning in an area does not mean that spawning does not occur there.

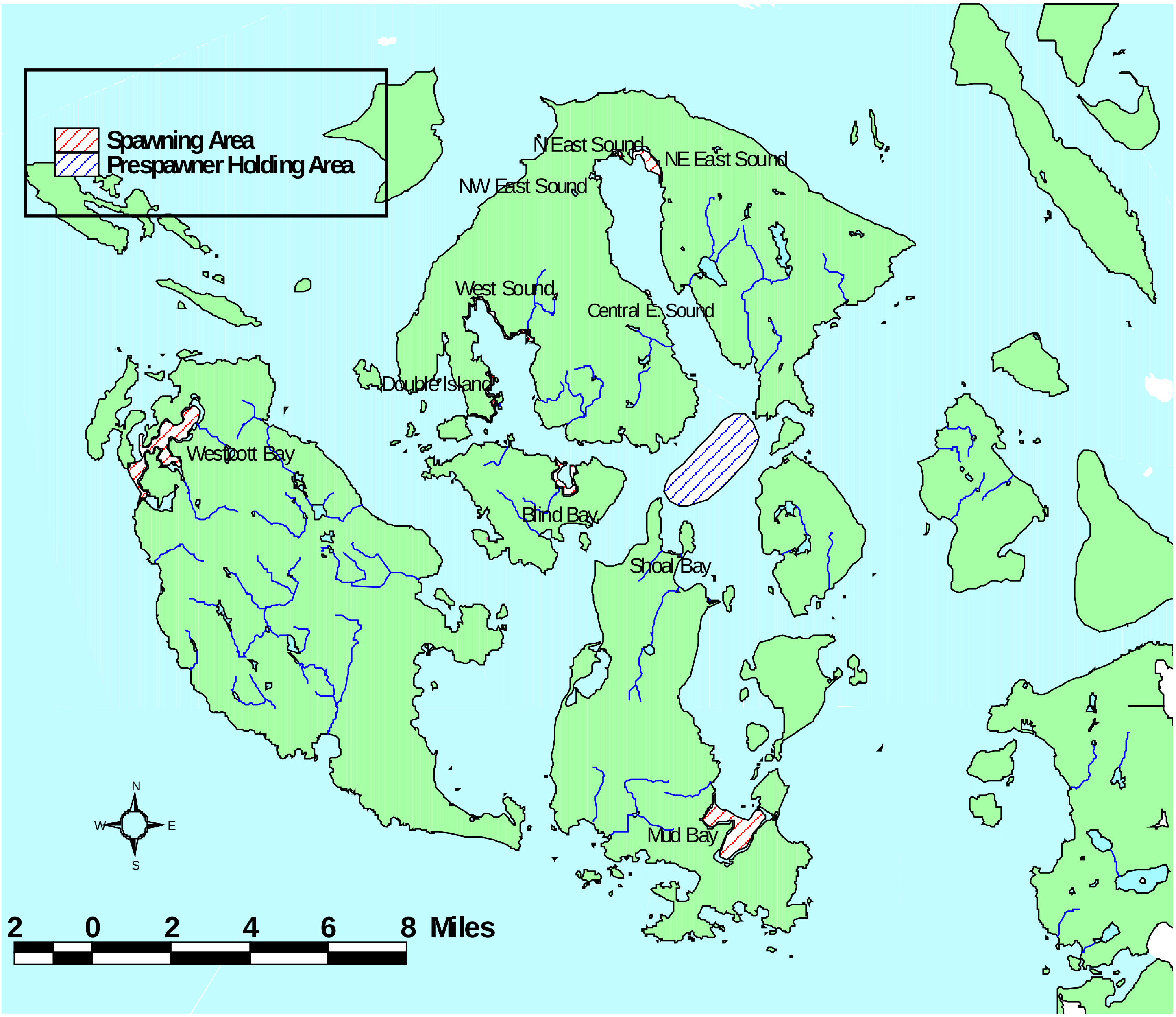
In WRIA 2, there are two identified herring stocks, one on northwest San Juan Island which spawns in Westcott Bay on San Juan Island, and another described as “Interior San Juan Islands” that spawns in West Sound and East Sound on Orcas Island, Blind Bay on Shaw Island, and Hunter Bay on Lopez Island. (Bargmann 1998, Moulton and Penttila 2000). These stocks spawning activity occurs from January through April. The estimated average run size for the time period 1977-1996 inclusive is 254 tons for the Interior San Juan Island stock and 200 tons for the Northwest San Juan Island stock(Lemberg et al. 1997). The stock status of these stocks is unknown.

<u>Historic Distribution and Use</u>

Pacific herring stocks in Puget Sound have undergone significant fluctuations, and some stocks have declined over the past 20 years. Bargmann (1998) reported that of the 18 identified herring stocks in Puget Sound 8 are in healthy condition, 1 in moderately healthy condition, 3 depressed, 1 critical and 6 in unknown condition. Since that time the status of the Cherry Point population, the largest population in Puget Sound and adjacent to the San Juan Islands, has decreased and the stock status is considered critical.

Distribution data for Puget Sound fishes compiled through 1973 show clusters of Pacific herring records within the nearshore areas throughout the San Juan Islands. A map showing the known distribution of herring spawning beaches in WRIA 2 can be found in Figure 2.

Figure 2: Known Pacific herring spawning areas



Historic records of Pacific herring within the WRIA 2 were mapped by Miller and Borton (1980), as reproduced in Moulton and Penttila (2000). These records indicate substantial use of nearshore area within and around the San Juan Islands.

Surf Smelt(*Hypomesus pretiosus*)

The surf smelt can be found in marine waters from southern California to central Alaska. These fish spend their entire life history in marine/estuarine waters. Inside Washington State waters they are widely distributed, occurring in coastal estuaries, the shores of the Olympic Peninsula, and the greater Puget Sound basin from Olympia to the US-Canada border including the San Juan Islands

Juveniles

Juvenile surf smelt reside in nearshore waters and may use estuaries for feeding and rearing (Emmett et al. 1991, Lemberg et al. 1997).

Adults

Adult surf smelt are pelagic, but remain in nearshore habitats over a variety of substrates throughout the year (Emmett et al. 1991). They feed on a variety of zooplankton and epibenthic organisms, including planktonic crustaceans and fish larvae (Emmett et al. 1991); (Fresh et al. 1981). Surf smelt in WRIA 2 are unusual in having an extended spawning season with some beaches receiving spawning activity year-round (Pentilla 1999). Spawning occurs on mixed sand-gravel beaches at a tidal elevation between approximately +2 m and the mean higher-high water line (Lemberg et al. 1997), or higher. Spawning stocks are presumed to have equal male:female sex ratio, but spawning schools are commonly dominated numerically by males, several of which attend each ripe female during the act of egg deposition. There is no evidence of widespread migrations to and from the outer coast and the relationship between spawning stocks and spawning grounds is not known. There is also no suggestion of large levels of mortalities among post spawning adult surf smelt.

Current Distribution and Use

Surf smelt are a widespread and important member of the nearshore fish community throughout Puget Sound. Although surf smelt movements within Puget Sound are unstudied, a number of genetically distinct stocks are thought to occur. Because no stock assessment studies have been done, the status of San Juan Island surf smelt populations is currently unknown. The initial studies of surf smelt in the Puget Sound basin in the 1930's did not map spawning beaches in WRIA 2. Subsequent discoveries of spawning sites in the Islands are presumably due to increased sampling effort, not an expansion of the range of this species (Penttila, pers. comm.).

Surf smelt spawn on the beaches of at least five islands in WRIA 2 (Appendix B). A lack of documented spawning in an area does not mean that spawning does not occur there because not all beaches have been surveyed and those that have do not always include data for multiple years.

Historic Distribution and Use

No reliable estimates of historical surf smelt distribution and habitat use exist for Puget Sound since spawning beach surveys were begun in 1972 (Pentilla 1978, Lemberg et al. 1997).

Pacific Sand Lance (*Ammodytes hexapterus*)

The Pacific sand lance is found from the marine waters of southern California around the north Pacific to the Sea of Japan and across Arctic Canada (Hart 1973). The fish is common in nearshore marine waters throughout Washington State.

There is very little direct information about the life history or biology of sand lance populations in the San Juan Islands or even Washington State. It is believed that because of their body shape and behavior that most standard types of net-fishing gear are not capable of capturing significant numbers of this species. Currently, no known sampling program by any local resource agency or research institution has yielded a comprehensive data set for adult sand lance populations in the San Juan Islands.

Field (1988) has summarized most of what is known of the biology of the sand lance populations of the Northeast Pacific Ocean. However, it is not clear that this information is directly applicable to Washington State stocks.

Juveniles

Pacific sand lance juveniles are pelagic and schooling, but may burrow into unconsolidated sediments at night to rest and escape predators. Juvenile sand lance are primarily planktivorous carnivores (Emmett et al. 1991). Juveniles rear in bays and nearshore waters (Lemberg et al. 1997) and are commonly found in eelgrass beds (King County, unpublished data).

Adults

Adult sand lance likely move into coastal and estuarine waters during spring and summer for feeding and refuge from predators (Emmett et al. 1991). Puget Sound sand lance populations appear to be obligate intertidal spawners with spawning occurring once a year from November to February at tidal elevations from +1.5 m to about the mean higher-high water line on sand to gravel beaches (Pentilla 1995, Lemberg et al. 1997). Several spawnings may occur at any given spawning site during the November-February spawning season (Pentilla pers comm).

Adult sand lance are planktivorous carnivores and prey heavily upon calanoid copepods (Fresh et al. 1981). In turn, juvenile and adult sand lance are a highly important prey item for many marine vertebrates and seabirds.

Current Distribution and Use

The Pacific sand lance (known locally as "candlefish") is a common but poorly known nearshore schooling baitfish in Washington waters (Pentilla 1995). However, they are highly abundant and widely distributed throughout Puget Sound bays and nearshore habitats (Emmett et al. 1991, Pentilla 1995). Over 140 miles of Puget Sound shoreline have been documented as sand lance spawning habitat (Penttila, pers. comm.).

Within WRIA 2 there are eight known or documented sand lance spawning locations including False Bay, Cattle Point and Jackson Beach on San Juan Island, MacKaye Harbor, Barlow Bay and Spencer Spit on Lopez Island, and Orcas Bay and East Sound on Orcas Island (Penttila, pers. comm.). There are numerous spawning locations along shorelines in adjacent waters. However, just because spawning is not documented in an area does not mean it does not occur there.

Historic Distribution and Use

No data were available regarding sand lance spawning habitats in the Islands before 1989 (Pentilla 1995). The actual spawning habitat of the Pacific sand lance was virtually unknown prior to the discovery of their spawn deposits in the upper intertidal zone of Port Gamble Bay in 1989 (Pentilla, pers. comm.). Historic abundance and habitat distribution and use are virtually unknown.

Longfin Smelt (*Spirinchus thaleichthys*)

The longfin smelt has been reported from San Francisco Bay, California to Prince William Sound, Alaska (Hart 1973).

Juveniles

Juvenile longfin smelt are most commonly associated with pelagic estuarine habitats. They are carnivorous planktivores and eat a variety of small crustaceans (Emmett et al. 1991).

Adults

Adult longfin smelt are abundant in estuarine habitats from Puget Sound to San Francisco Bay. Spawning occurs in freshwater areas at night during winter and over sandy areas with aquatic vegetation; most adults die soon after spawning (Emmett et al 1991). Adults are carnivorous zooplanktivores and are consumed by numerous marine and estuarine vertebrates (Emmett et al. 1991).

Current Distribution and Use

In WRIA 2, longfin smelt appear to have an established population in East Sound and possibly West Sound, Orcas Island (Miller and Borton 1980). Longfin smelt spawn in sand and gravel areas in the lower reaches of rivers and streams, but so far spawning areas in San Juan County have not been identified. Small streams entering East Sound and the eastern shore of West Sound are likely spawning areas. Hart (1973) reported that in January around the Islands adult male and female longfin smelt averaged 117 millimeters and 106 millimeters in standard length. The confirmation of longfin smelt spawning sites, timing, substrate utilization, and early life history requirements may be critical for its survival, and for its habitat needs to be taken into account in the Islands.

Historic Distribution and Use

Hart (1973) identified longfin smelt as being present in the San Juan Islands but he did not identify the source of his information. More recently, Miller and Borton (1980) mapped all records of longfin smelt from the San Juan Islands. Most of the records were from East Sound, Orcas Island, with additional records from West Sound. A few scattered records were also found in the region.

All Forage Fish

Reasons for Change

Herring has been the most actively managed forage fish species in Washington State. The emphasis for this management is primarily due to the large commercial fisheries for sac-roe, as baitfish, and the resulting economic value. By 1900, the destruction of herring and smelt spawning habitats was causing concerns by natural resource managers and was largely blamed for greatly reducing the abundance of the species. During 1915 several herring reserves were closed to fishing during spawning season.

An increase in the natural mortality for herring over the last 20 years has been attributed to increased predation pressure (Lemberg et al. 1997). There are many species of fish that feed on forage fish. Major predators include Pacific cod (42% of diet), whiting (32%), lingcod (71%), halibut (53%), coho salmon (58%) and chinook salmon (58%). Site specific data for the importance of herring to salmon stocks in the Islands is not available. However, in the Strait of Georgia, immediately adjacent to the Islands, forage fish, primarily herring, comprised up to 65% of the diet of chinook (Healy 1982). Gearin et al (1994) reported in their study that adult chinook salmon were feeding primarily on herring and to a lesser extent sand lance. Another study reported that in the Strait of Georgia herring and sand lance made up 29-35% of the diet of coho salmon.

Marine mammals also prey heavily on forage fish; 32% of the diet of harbor seals in British Columbia is comprised of herring (Hay and McCarter 1995). Harbor porpoises captured in the Strait of Juan de Fuca feed heavily on herring and smelt. Smelt and herring comprised 64% and 89% of the fish remains recovered from the stomachs of harbor porpoises. Adult porpoises feed primarily on herring and subadults feed on both smelt and herring (Gearin et al 1994).

Individual herring stocks vary greatly in relative size and may undergo significant fluctuations in recruitment and adult survival due to variations in marine ecological conditions and prey resources, alterations in nearshore habitats, and fishery overharvest (Lemberg et al. 1997, West 1997). The size of a population may vary greatly over a short period of time and abundance varied considerably even prior to the initiation of modern fisheries. Much of the variation in population size is thought to occur due to environmental conditions (Bargmann 1998). However, fishing may have increased the natural variability due to decreased stock sizes and harvest of older fish. The decrease of the population of the Cherry Point stock is a special concern because of its size and proximity to the Islands.

No data are available for smelt and sand lance.

Stressors

The commercial overharvest of herring to supply bait needs and for sac-roe occur have resulted in fisheries closures (Bargmann 1998). Surf smelt also are affected by large commercial and recreational harvests that average more than 200 tons annually (Lemberg et al. 1997). Pollution, thermal stress, and desiccation can result in egg and larval mortality (Emmett et al. 1991).

Herring, surf smelt, and sand lance have specific spawning habitat requirements, which make them especially vulnerable to shoreline development activities (Lemberg et al. 1997, Pentilla 1978, Pentilla 2000). For example, shoreline armoring has been implicated in the loss and alteration of beach substrate that supports eelgrass and forage fish spawning (Thom and Hallum 1990; Thom and Shreffler 1994). Loss of overhanging riparian vegetation along shorelines may reduce shading and result in reduced survival of these species' eggs and larvae (Pentilla 2000).

Data Gaps

Reasons for increased natural mortality in herring are unclear, especially in light of the relatively low recent abundance levels of many of the Puget Sound herring predators.

Smelt migrations and movements of surf smelt are unstudied, and it is unclear if adults return to natal spawning beaches or exhibit fidelity to specific spawning beaches. In fact, little basic biological information exists for all forage fish in Puget Sound. Stock assessments, dietary studies, additional spawning surveys, and information about other life history requirements are needed for all forage fish (Table 17) (Bargmann 1998).

Currently, an effort to identify additional forage fish spawning beaches in the Islands is being coordinated by the San Juan County Marine Resources Committee. Results are only preliminary but surveys have identified numerous previously undocumented spawning beaches for Pacific herring and smelt.

Table 17: Data gaps for forage fish

Data Gaps
Reasons for increased mortality of Pacific herring
Water quality effects on nursery grounds and young-of-year
Complete life history requirements of forage fish species
Information on forage fish stocks and biomass
Complete spawning ground surveys
Quantitative data on the effects of shoreline armoring and other shoreline development on spawning grounds

Key Findings

- Forage fish found within or expected in the nearshore marine habitats of WRIA 2 include herring, surf smelt, and Pacific sand lance. Forage fish use these habitats for feeding, migration, spawning, and rearing.
- Forage fish represent a significant component of the San Juan Island food web.
- Herring natural mortality in Puget Sound has increased in recent years.
- Herring return to natal spawning grounds; egg attachment sites include firm substrates such as eelgrass and macroalgae. Sand lance and surf smelt spawn on upper intertidal beach habitats with sand/gravel sediments. All of these habitats are especially vulnerable to shoreline development.
- Within WRIA 2, there are numerous known herring spawning areas and a number of documented surf smelt and Pacific sand lance spawning beaches.
- Continuing studies are documenting additional forage fish spawning areas.

Overwater Structures

Types and Distribution

Overwater structures in the marine waters of WRIA 2 include floating docks, piers, pilings, marinas, barges, rafts, booms, mooring buoys, and floating breakwaters.

There is limited information on the distribution and abundance of overwater structures in the marine waters of WRIA 2. Floating docks and mooring buoys are common around throughout the San Juan Islands. Marinas in the San Juan Islands include formal marinas where dock space is rented or purchased, and facilities available to island property owners as part of land ownership. In WRIA 2 there are 7 marinas on San Juan Island, 5 on Lopez Island, 2 on Shaw Island, 4 on Orcas Island, 1 on Blakely Island, 1 on Decatur Island.

According to the Shoreline Management Act, houseboats are not allowed anywhere in the state except limited locations in Lake Union (WRIA 8) and Portage Bay (WRIA 8). Piers often serve as a connection between floating docks and the upland. Pilings are widely scattered around the San Juan Islands. Typically they are associated with docks and relics of long abandoned shoreline activities. Barges, rafts, and booms are typically associated with overwater industrial activities and often are relocated to various work sites.

Effects upon Nearshore Ecosystem

Overwater structures are located in the nearshore zone. Typically, these structures alter the levels of light, shoreline energy regimes, substrate type and stability, and may locally degrade water quality (Nightingale B. and Simenstad C. 2000). These habitat changes can then result in altered abundance and diversity of plant and animal species in nearshore marine ecosystems. Overwater structures can alter wave energy and sediment dynamics, affecting substrate size, type and stability, plant propagation, fish foraging, spawning and migration, and shellfish settlement and rearing. Overwater structures can also affect the seabed, disturbing or destroying benthic organisms and vegetative growth.

Simenstad et al (1998) demonstrated that docks, piers, and pilings can interfere with the light for plant growth and propagation. The area (footprint) of shade created by overwater structures is related to the structure size, height, height above the water, orientation to the sun, and the construction materials ((Olson et al. 1996). Fixed floating docks completely block the light to the surface, creating constant shade for an unchanging area while those anchored by chains move and allow for light penetration to areas as they are uncovered (Pentilla and Doty 1990). Marinas are groupings of individual piers, often behind a breakwater, where large areas of light reduction can occur. Barges, rafts, booms, and floating breakwaters block light and can affect plant reproduction within one week (Pentilla and Doty 1990).

Studies of marinas have found fish near the shoreline and perimeter of the marina, but not in the dark areas under the docks and moored boats (Nightingale B. and Simenstad C. 2000). Avian predation on fish in marinas did not appear to be related to the floating docks and moored vessels. Studies have found fewer juvenile fish under piers than in surrounding open waters and reveal that piers supported by piles interfere with the migration of fish (Able et al. 1998); (Nightingale B. and Simenstad C. 2000). The construction of piers increases turbidity and the sound of pile driving can influence fish behavior. Floating breakwaters allow for improved fish passage over conventional solid breakwaters, but their impacts on fish behavior are not fully understood (Nightingale B. and Simenstad C. 2000). Where barges, rafts, vessels, and booms grind into the nearshore bottom, this can kill benthic and intertidal organisms and plants and disrupt the substrate habitat.

In the San Juan Islands (WRIA 2) marinas that are located behind a breakwater, result in changes in wave energy and sediment transport occur with their presence. Other marinas are located in embayments with low wave energy where a breakwater is unnecessary, or limited to a floating breakwater. The chains that anchor mooring buoys can scour the substrate and destroy vegetation and benthic organisms.

In addition to the effects of overwater structures, additional impacts may occur as a result of vessels temporarily or permanently moored to those structures. Boats add additional shading, and props can scour the bottom affecting benthic organisms and plants. Boat discharges introduce contaminants and nutrients, changing the habitat that plant and animal species require (Nightingale B. and Simenstad C. 2000). The water quality in marinas is affected by boat engine exhaust, fuel and lubricant spills, sewage discharge, and contaminated stormwater runoff coming from parking lots close to the marina.

Even when utilizing “Best Management Practices”, the construction and maintenance practices associated with overwater structures can result in adverse impacts to aquatic habitats and plant and animal species. Activities such as dredging, filling and pile driving can result in short-term and long-term disturbance, or modification of physical and biological processes. For example, dredging and construction materials (i.e., creosote treated piles) used in marine construction result in contaminant releases. Dredging and the placement of inwater structures alters sediment distribution and composition, hydrology, and biological community composition as a result of habitat alterations that occur with each construction or maintenance event.

Data Gaps

There is limited information on the distribution and abundance of overwater structures in the San Juan Islands. Additional information on the effects of overwater structures on plant and animal communities is needed. Table 18 lists specific data gaps for overwater structures.

Table 18: Data gaps for overwater structures

Data Gaps
The cumulative and site-specific effects of overwater structures on nearshore processes and biological communities
Effective alternatives to and mitigation measures for docks and piers
Quantified relationships between overwater structures and alteration of predation rates on specific prey species including forage fish and juvenile salmonids

HABITAT LIMITING FACTORS

Habitat Limiting Factors used by the Washington Conservation Commission

Loss of Access to Spawning and Rearing Habitat: This category includes culverts, tide gates, levees, dams, and other anthropogenic structures that restrict access to spawning habitat for adult salmonids or rearing habitats for juveniles. Additional factors considered are low stream flow or temperature conditions that function as barriers during certain times of the year.

Freshwater and Tidal Flooding: Floodplains are relatively flat areas adjacent to larger streams and rivers that are periodically inundated during high flows. In a natural state, they allow for the lateral migration of the stream channel and provide storage for flood waters, sediment and woody debris. Floodplains generally contain numerous sloughs, side channels, and other features that provide important spawning habitat, rearing habitat, and refugia for organisms during high streamflows. Along the coastline of the San Juan Islands, salt marshes and mini-estuaries are also, under natural conditions, exposed to flooding twice a day from tidal waters. The tides flush nutrients into and out of these habitats and provide vegetation and organisms with the saline environment they require to survive.

This category includes the direct loss of habitat from human activities in floodplains (e.g.: filling) and the disconnection of main channels from floodplains with dikes, levees and revetments. Disconnection can also cause changes in hydrology and/or sediment inputs.

Channel Conditions and Sediment: This category addresses instream habitat characteristics that are not adequately captured by another category such as bank stability, pools, and large woody debris. Changes in these characteristics are often symptoms of impacts to ecosystem processes elsewhere in the watershed.

Changes in the inputs of fine and coarse sediments to stream channels can have a broad range of effects on salmonid habitats. Increases in coarse sediments can create stream channel instability and reduce the frequency and volume of pools, while decreases can limit the availability of spawning gravels. Increases in fine sediments can fill pools, decrease the survival rate of salmonid eggs deposited in redds, and lower the production of benthic invertebrates. This category addresses these and other sediment related habitat impacts caused by human activities throughout the watershed. This includes increases from landslides, road construction and maintenance, agricultural practices, construction activities, and streambank erosion; decreases in gravel availability caused by floodplain constriction; and changes in sediment transport brought about by altered hydrology and reduction of large woody debris.

Riparian Conditions: Riparian areas include the land adjacent to streams and nearshore environments that interacts with the aquatic environment. This category addresses factors that limit the ability of native riparian vegetation to provide shade, nutrients, bank stability and as a recruitment source of large woody debris. Riparian impacts include timber harvest, clearing for agriculture or development, construction of roads, dikes, or other structures and direct access of livestock to stream channels.

Water Quality: Water quality factors addressed by this category include stream temperature, dissolved oxygen, and pollutants that can directly affect salmonid production.

Water Quantity: Changes in flow conditions can have numerous effects on salmonid habitats. Low flows can reduce the availability of summer rearing habitat and contribute to increased water temperature, low dissolved oxygen, and access restrictions. High peak flows can scour out or transport sediment into spawning areas. Other alterations to seasonal hydrology can result in the stranding of fish or limit the availability of habitat at various stages. All types of hydrologic changes can alter channel and floodplain complexity. This category addresses changes in flow conditions brought about by water withdrawals, the presence of roads, the alterations of floodplains and wetlands and a variety of land use practices.

Estuarine and Nearshore Habitat: This category addresses habitat impacts that are unique to the estuarine and marine nearshore environments.

Estuarine habitats include areas in and around the mouths of streams extending throughout the area of tidal influence on freshwater. These areas provide important rearing habitat. Impacts include the loss of habitat complexity due to road construction, the alteration of native riparian habitats, and the loss of tidal connectivity caused by tidegates.

Nearshore habitat includes intertidal and shallow subtidal saltwater areas adjacent to land that provides transportation and rearing habitat for adult and juvenile salmonids. Important features of these areas include eelgrass, kelp forests, large woody debris, and the availability of prey species. Anthropogenic impacts include bank hardening features such as bulkheads, overwater structures, filling and the alteration of longshore sediment transport processes.

Biological Processes: This category addresses impacts to fish caused by interactions with other species. Some examples include the introduction of exotic (non-native) plant and animal species, and the loss of ocean-derived nutrients due to the amount of available salmon carcasses.

WATERSHED CONDITION

General Overview

Most of the 175 square miles of land is on the five largest islands: San Juan, Orcas, Lopez, Shaw and Cypress. The next largest island is Blakely, encompassing 7 square miles roughly in the center of the island group. There are also an additional 500 plus identified rocks and reefs.

The San Juan Islands includes in excess of 85 identified freshwater streams. Williams (1975) identified approximately 100 miles of stream habitat in the Islands but did not address accessibility issues for anadromous salmonids. The WDNR hydrolayer identifies a minimum of 83 streams on Orcas Island, 64 on San Juan Island, 20 on Lopez Island, 18 on Shaw Island, and 6 on Blakely Island with an estimated total 158 miles. Only a few of these streams are naturally accessible to anadromous salmonids as the vast majority have confluences with the marine environment that are naturally perched or enter at a gradient too steep for anadromous salmonid access. These streams generally have low levels of impervious surfaces and many have altered hydrologic regimes, poor riparian conditions and seasonal low flows. There are no known naturally sustaining populations of anadromous or resident salmonids in the freshwater habitats of WRIA 2. However, the value to anadromous salmonids lies within the nearshore habitats described previously in this report.

In this chapter, the lakes and streams that are or may have been accessible to anadromous salmonids of the San Juan Islands (WRIA 2) are subdivided by the islands on which they occur. The first two digits (02) refer to WRIA 2, while the next four digit numbers in parentheses following the stream name are according to the Catalog of Streams and Salmon Utilization (Williams 1975).

- Blakely Island
    - Horseshoe and Spencer Lakes
- Lopez Island
- Orcas Island
    - Cascade Creek (02.0057)
    - Mountain Lake
    - Cascade Lake
    - Crow Valley Creek (02.0072)
- San Juan Island
    - Egg, Trout and Sportsman Lakes
    - Unnamed tributary (02.0041)
    - False Bay Watershed including unnamed tributary (02.0027)

There are numerous additional tributary streams on the Islands that are not covered in this assessment. Generally these streams do not have anadromous fish access or have very limited amounts of access. However, the absence of these creeks in this report should not be interpreted as diminishing their importance, rather the lack of information that was located during the course of this investigation.

Because of lack of land mass. the vast majority of the islands in WRIA 2 do not have streams or have only seasonal streams.

A. Blakely Island

A.1. Physical Description

Blakely Island is a privately held island approximately 4700 acres (seven square miles) in size, is sparsely populated and little developed. The island is the largest of the non-ferry served islands in San Juan County. Approximately 80 percent of the island is owned or held in trust by Seattle Pacific University as an environmental research center. The highest point on the island is 1000 feet.

The two major bodies of water on the island are Horseshoe and Spencer lakes. Horseshoe Lake, also sometimes known as Luna or Blakely Lake, is approximately 84.0 acres in size, with a maximum depth of 92 feet, and drains to Spencer Lake. Spencer Lake (also sometimes referred to as Wildwood or Thatcher Lake) is approximately 64.0 acres in size with a maximum depth of 72 feet. Spencer Lake drains to Thatcher Bay.

A.2. Watershed Condition

Except for the developed community on the north end of the island, with a marina and a small plane airstrip, covenants only allow for a maximum of sixty lots. A review of satellite imagery (http://terraserver.homeadvisor.msn.com/image) indicates no active logging or resource extraction activities on the island.

A.3. Salmonid Utilization

There are no known anadromous salmonids utilizing the freshwater habitats of Blakely Island. Historically, anadromous salmonids are not known to have utilized the freshwater habitats of Blakely Island. Brown trout have been planted into Spencer Lake and rainbow trout have been released into both Horseshoe and Spencer Lakes, however neither lake has tributary streams capable of supporting naturally reproducing populations of these species (Johnston pers. comm.).

The known freshwater distribution of anadromous and resident salmonid species is depicted Appendix A.

A.4. Fish Access and Passage Barriers

There are no known anthropogenic caused habitat limiting factors to natural salmonid production. The freshwater habitats of Blakely Island are not thought to historically have had naturally producing anadromous or resident salmonid populations.

A.5. Degradation of Riparian Conditions

No information on riparian conditions on Blakely Island was obtained during the course of this investigation. However, a review of current satellite imagery at: http://terraserver.homeadvisor.msn.com/image indicates that riparian habitats should be considered to be in fair to good condition.

A.6. Loss of Channel Complexity/Connectivity

A powerhouse exists on the outlet stream to Spencer Lake.

A.7. Altered Stream Hydrology/Flow

A powerhouse exists on the outlet stream to Spencer Lake.

A.8 Water Quality

No water quality problems have been identified in this basin.

A.9 Biological Processes

There was no information obtained during the course of this investigation that indicated salmon utilization of freshwater streams in this watershed. The Washington Department of Fish and Wildlife Spawning Ground Survey Database does not contain any observations of salmon in this watershed.

Key Findings and Identified Habitat-limiting Factors

- The freshwater habitats of Blakely Island are not thought to historically have had naturally producing anadromous or resident salmonid populations.
- A review of current satellite imagery at: http://terraserver.homeadvisor.msn.com/image indicates that riparian habitats should be considered to be in fair to good condition.

Data Gaps

- No water quality problems have been identified in this basin.
- A powerhouse exists on the outlet stream to Spencer Lake and the impacts of this facility to stream hydrology is unknown.

B. Lopez Island

There is no known utilization of freshwater habitat by anadromous salmonids on Lopez Island. Hummel Lake, located in the center of the island and east of Lopez Village, has received plants of rainbow trout, large-mouth bass, yellow perch, black crappie and brown bullhead (Johnston pers. comm). However, the habitat of this lake does not allow for natural production of the planted rainbow trout and to sustain fisheries additional releases are necessary (Johnston pers. comm).

C. Orcas Island

C.1. Deer Harbor Watershed

C.1.1. Physical Description

Physical Description: The Deer Harbor Watershed is located on the western portion of Orcas Island. The depth of the harbor is estimated to be 30 to 45 feet deep depending on tidal levels.

At the northern end of Deer Harbor, the Frank Richardson Preserve is a freshwater marsh area of approximately 20 acres that combines with the unnamed tributary 02.0076 and drains into northern Deer Harbor. A second stream drainage flows from two tributaries at the head of Deer Harbor Lagoon creating a unique estuary where freshwater enters this tidally influenced lagoon. Most of the Deer Harbor Lagoon is under conservation easement with the San Juan County Land Bank. A third stream (02.0077) enters Deer Harbor from the west.

C.1.2. Watershed Condition

Land use in the Deer Harbor watershed is principally single family residential with some agriculture. There is also a small resort development at the village of Deer Harbor and two marinas. Coniferous forests dominate the land cover (60 percent of watershed) while grasslands cover about 22 percent of the watershed. Of these lands between 10 and 15 percent are in active agriculture and primarily used for livestock grazing and hay production. Tables 19 and 20 summarize land use in the watershed.

Table 19: Summary of Habitat Types in the Deer Harbor Watershed (Source: San Juan County 2000)

Landcover Vegetation	Acreage	Percentage
Grasses and Forbs	403	22%
Dense Forest	858	47%
Sparse Forest	224	12%
Scrub	288	16%
Watershed Acreage Total	1,808	
Wetlands	**Acreage**	
Upland freshwater	65	3%
Marine and intertidal	60	
Lakes	**Acreage**	
none		
Streams	**Miles**	
Class 3	0.4	
Class 4/5	2	
Drainage runoff	**acre-feet**	
	unknown	

Table 20: Summary of Current Land Use* in the Deer Harbor Watershed

(Source: San Juan County 2000)

Classification	Acres	Percentage
Agriculture	35	2%
Timber Land	221	12%
Conservation	70	4%
Residential parcels	432	24%
Public Lands	0	0%

* Current land use information is from the San Juan County Assessor Office.

C.1.3. Salmonid Utilization

There currently does not appear to be any anadromous salmonid utilization of this system.

The known freshwater distribution of anadromous and resident salmonids is depicted in Appendix A.

C.1.4. Fish Access and Passage Barriers

A comprehensive barrier assessment survey has not been initiated and no data on barriers was located during the course of this investigation. There are a minimum of three road crossing across streams in this watershed.

C.1.5. Degradation of Riparian Conditions

There is some local logging in the watershed but generally not in the vicinity of the small creeks present. Dense Himalayan blackberry thickets and early seral stage deciduous trees are present in the riparian habitats throughout the watershed.

C.1.6. Loss of Channel Complexity/Connectivity

USGS Quad maps indicate that portions of the western stream (02.0077) has been channelized.

C.1.7. Altered Stream Hydrology/Flow

A large portion of the watershed and all of the marine shoreline has high erosion potential. Damage to local roads caused by erosion occurred in the watershed between Deer Harbor Resort and Pole Pass in 1998. Additionally, soils are not suitable for septic disposal in the watershed (San Juan County 2000).

C.1.8. Water Quality

No water quality problems have been identified in this basin but sampling has been sporadic.

C.1.9. Biological Processes

There was no information obtained during the course of this investigation that indicated salmon utilization of freshwater streams in this watershed. The Washington Department of Fish and Wildlife Spawning Ground Survey Database does not contain any observations of salmon in this watershed.

Key Findings and Identified Habitat-limiting Factors

- Land use in the Deer Harbor watershed is principally single family residential with some agriculture.
- Coniferous forests dominate the land cover (60 percent of watershed) while grasslands cover about 22 percent of the watershed. Of these lands between 10 and 15 percent are in active agriculture and primarily used for livestock grazing and hay production.
- There currently does not appear to be any anadromous salmonid utilization of this watershed.
- USGS Quad maps indicate that portions of the western stream (02.0077) has been channelized.

Data Gaps

- A comprehensive fish barrier assessment survey has not been initiated and no data on barriers was located during the course of this investigation.
- Water quality sampling has been sporadic.

C.2. Eastsound Watershed

C.2.1. Physical Description

Physical Description: The East Sound watershed has several important wetlands, including the Crescent Beach wetland (a 5.5 acre brackish marsh), Otter's Pond, and the Eastsound swale, which was historically a large wetland but has been greatly reduced and altered by adjacent development (San Juan County 2000). The Woolard Mountain - Diamond Hill area site is unique in that it is mostly undeveloped with several stands of virgin western hemlock, which is the climax forest species for this site. Entrance Mountain has a large stand of Sitka Spruce.

Land use within the watershed is primary residential, with some forestry and agriculture. Eastsound Village, at the northern end of East Sound, is the second largest town in the county, but is unincorporated. Rosario Resort and its marina also occur in the watershed. Land cover in the East Sound watershed is primarily forest land (70% of watershed), with some grass (14%) and scrub (15%) lands (San Juan County 2000).

East Sound is approximately 7 miles in length and approximately 1½ miles wide at its widest point. Water depths slope from the shoreline to a fairly uniform 90 feet throughout its length. Inside the boundaries of the watershed is Moran State Park, which is 5252 acres in size. There are two Class 1 Lakes in the watershed, Cascade Lake (171.6 acres and estimated 15 feet deep) and Mountain Lake (198 acres and an estimated 100+ feet deep). Summit Lake (10 acres and estimated at 10 feet deep) is a Class 2 lake, and is also located inside the boundary of Moran State Park. Other significant lakes in the watershed include Martins Lake (27.8 acres, Class 1), and two Class 2 impoundments called Ayer Reservoir (10.3 acres) and Flaherty's Pond (2.5 acres). There are also numerous smaller ponds distributed throughout the watershed.

Streams flowing to East Sound include Cascade Creek (02.0057) which flows into Buck Bay. A creek that originates from Ayer reservoir and another creek that begins near the head of Crow Valley and flows through Fowlers Pond drains northeast into Judd Cove. Numerous other creeks exist in the watershed, though the majority are seasonal.

C.2.2. Watershed Condition

Table 21: Summary of habitat types in the East Sound Watershed (Source: San Juan County 2000)

Landcover Vegetation	Acreage	Percentage
Grasses and Forbs	1,626	12%
Dense Forest	8,947	64%
Sparse Forest	736	5%
Scrub	1,997	14%
Watershed Acreage Total	13,933	
Wetlands	**Acreage**	
Upland freshwater	358	
Marine and intertidal	517	
Lakes	**Acreage**	
Class 1 – Cascade Lake	172	
Mountain Lake	198	
Martins ~~-~~Lake	28	
Class 2 – Summit	10	
Ayres	10	
Flaherty's	2.5	
Fowlers	9	
Class 3	3	
Lakes/Freshwater	6 %	
Streams	**Miles**	
Class 3	4.2	
Class 4/5	9.5	
Drainage runoff	**acre-feet**	
	1899	

Table 22: Summary of current land use* in the East Sound watershed

(Source: San Juan County 2000)

Classification	Acres	Percentage
Agriculture	479	3%
Timber Land	1,754	13%
Conservation	1,256	9%
Residential parcels (813)	2,174	16%
Public Lands	3,783	27%

* Current land use information is from the San Juan County Assessor Office.

Of special note is the log rafting operation in Judd Cove at the northern end of East Sound.

C.2.3. Salmonid Utilization

Cascade (02.0057) and Cold (02.0060) creeks are year-round streams. Williams (1973) reported that Cascade Creek supported coho salmon and San Juan County (2000) reported anadromous fish in Cold Creek but did not identify the species. The WDFW Spawning Ground Survey database does not have any entries for either Cascade or Cold creeks. Both Cascade and Cold Creeks have been established as a priority for Searun Cutthroat trout and Coho salmon by Washington Department of Fish and Wildlife (1999). A private salmon hatchery operated by the non-profit organization *Long Live the Kings* releases chinook, coho, and chum salmon in the vicinity of Giffin Rocks on the eastern shore of East Sound.

Chum and pink fry have been reported in the saltwater areas of Buck Bay (Castle pers. comm) in the vicinity of the mouth of Cascade Creek while juvenile coho salmon and cutthroat trout fingerlings have been reported in the lower stream reaches of Cascade Creek (Johnston pers. comm).

The known freshwater distribution of anadromous and resident salmonids is depicted in Appendix A.

C.2.4. Fish Access and Passage Barriers

A comprehensive barrier assessment survey has not been initiated and no data on barriers was located during the course of this investigation. Cascade Creek has a minimum of three road crossing and a county road (Horseshoe Highway) limits lateral stream migration at several locations. During a site visit on September 26, 2001, a water diversion dam was observed at RM 1.6 of Cascade Creek. This diversion, had a wire mesh screen across the intake to the pipe but did not appear to meet screening requirements established by WDFW. Additionally, on that site visit, the entire stream flow of Cascade Creek was diverted into a corrugated aluminum pipe. The dam serves as a complete barrier to upstream fish migration.

C.2.5. Degradation of Riparian Conditions

There is some local logging in the watershed of Cascade Creek but generally not in the vicinity of Cascade Creek. In the downstream reaches of Cascade Creek just above tidewater the creek flows through dense Himalayan blackberry thickets and early seral stage deciduous trees.

C.2.6. Loss of Channel Complexity/Connectivity

The only constraining factor inside the anadromous fish zone is the one road crossing where Horseshoe Highway crosses Cascade Creek near Buck Bay. Other road crossings are outside of the anadromous zone. However, Horseshoe Highway does serve to constrain the lateral movement of Cascade Creek south of the Moran State Park boundary.

C.2.7. Altered Stream Hydrology/Flow

No information on altered stream flows was obtained during the course of this investigation. The diversion dam mentioned previously completely dewatered Cascade Creek until either leakage from the pipe or tributary inflow provided baseflow.

C.2.8. Water Quality

While none of the streams appear on the WDOE 1998 303d water quality list several problems have been reported.

Results from the initial water quality survey of the East Sound watershed indicated that most sampling locations met state water quality standards for all parameters. However, several locations that did not meet current water quality standards. These included the stormwater outlet in the village of East Sound across Horseshoe Highway from the Outlook Inn (Station *O11*), the unnamed creek (02.0064) to Judd Cove (Station *O10*) and Pickett Springs (Station O1) and Cascade Creek (Station O2) (San Juan County 2000). During additional water quality monitoring performed from November through February (1997-1998) water quality samples from the East Sound storm drain exceeded total suspended solids (TSS) thresholds on two occasions and one small tributary to East Sound exceeded TSS the only time a sample was taken. On one occasion, the sample obtained from the East Sound storm drain reached the upper limit of pH thresholds but all other results were within acceptable ranges. While not directly impacting salmonids it should be noted that in the Buck Bay area, increased fecal coliform counts are attributed to failing septic systems. These failing septic systems have been documented over the years primarily where homes were built prior to the design requirements for septic permits.

The village of Eastsound has the largest concentration of impervious area on Orcas Island. A stormwater collection system collects surface water runoff from impervious surfaces (e.g.: streets, parking lots, and buildings) and pipes the water directly into East Sound with no treatment. The only exception is the parking lots from Island Market which drain in to a constructed wetland provided for stormwater treatment. Contamination of the saltwater from freshwater entering Fishing Bay via the storm drain was documented in 1996 by Parsons and Ogier. San Juan County has purchased property and conducted the design process to build a biofiltration facility in the East Sound drainage but this facility has not yet received complete funding.

C.2.9. Biological Processes

The Washington Department of Fish and Wildlife Spawning Ground Survey Database does not contain any observations of salmon in this watershed. However, numerous observations by local residents indicate that anadromous salmonids utilize the lower 0.5 mile of Cascade Creek. Searun cutthroat trout have been observed in Cascade Creek (Johnston pers comm) and off the mouth of the creek in Buck Bay (Kerwin pers obs.).

Key Findings and Identified Habitat-limiting Factors

- Land use within the watershed is primary residential, with some forestry and agriculture.
- Land cover in the East Sound watershed is primarily forest land (70% of watershed), with some grass (14%) and scrub (15%) lands (San Juan County 2000).
- Juvenile coho salmon and cutthroat trout fingerlings have been reported in the lower stream reaches of Cascade Creek.
- Chum and pink fry have been reported in the saltwater areas of Buck Bay.
- A water diversion dam at RM 1.6 of Cascade Creek has a wire mesh screen across the intake to the pipe but did not appear to meet screening requirements established by WDFW. Additionally, the entire stream flow of Cascade Creek is diverted into a corrugated aluminum pipe at this location.

Data Gaps

- Water quality sampling in Cascade Creek and Cold Creek has been sporadic.
- Data on the quality and buffer zones of riparian habitats of Cascade Creek outside of Moran State Park was not located during the course of this investigation.
- The utilization of Cascade and Cold Creeks by resident and anadromous salmonids needs to be more fully understood.

D. San Juan Island

D.1. False Bay Watershed

D.1.1. Physical Description

Physical Description: The False Bay watershed is the largest watershed in the San Juan Islands at 11,697 acres. Water in the basin is the source of the majority of potable water for the town of Friday Harbor. It also contains the most extensive grassland acreage as well as the most actively used farmland in San Juan County. The basin has several origins from springs, seeps and lakes all near Cady Mountain and terminates in False Bay. False Bay is also a marine biological preserve belonging to the state of Washington and administered by the University of Washington Friday Harbor Laboratories. This reserve includes 200 acres of tidelands and uplands at the bay.

False Bay consists of a large area of tidal flats and portions of the upland lands are held as a wildlife preserve. This preserves and provides excellent habitat for a high diversity of plants, birds, and sea life, including many intertidal species generally found on the open coast (e.g.: Giant Green Anemones, Gooseneck Barnacles, and California Mussels). The bay currently does not have any recreational or commercial fishing or shellfish activities. However, historically abalone and sea urchins were harvested in the outer coastal waters of the watershed.

Substantial eelgrass beds and kelp forests are located at the mouth and along the coastline adjacent to the bay. The watershed has the largest amount of identified wetland acreage of all the watersheds in the county. There are at least two streams of significance draining to

False Bay with numerous tributaries stemming from all portions of the watershed. The largest creek, San Juan Creek (02.0027), is the only Class 2 creek in the county.

Located in this watershed, Trout Lake, a Class 1 type waterbody, is the principal water supply for the town of Friday Harbor, and supplies water to a large portion of the island's population. Lawson Lake is a 12.5 acre Class 1 type waterbody that augments Friday Harbor's water supply. Wood Reservoir is a 29 acre, Class 2 impoundment. Zylstra Lake is a constructed 70 acre impoundment used to provide irrigation water. There are also several Class 2 through 5 water bodies less than 5 acres in size.

D.1.2. Watershed Condition

Agricultural uses in False Bay are continuing their historic presence with land gradually being converted to rural-residential use. The dominant agricultural use is livestock operations that include sheep, cattle, and horses (Kerwin pers obs.). A field survey during the winter of 1997-98 suggested that most of the grazing fields were in fair condition, but some overgrazing and poor management was apparent (San Juan County 2000). During the winter most of the valley bottom fields are saturated with standing pools of water. During that same survey, some animals were being pastured through the winter with direct access to the creeks and saturated areas. Tables 23 and 24 provide summaries of land use in this watershed.

Table 23: Summary of habitat types in the False Bay Watershed (Source: San Juan County 2000)

Landcover Vegetation		**Percentage**
Grasses and Forbs	5,286	**45%**
Dense Forest	3,040	26%
Sparse Forest	1,030	9%
Scrub	2,106	18%
Watershed Acreage Total	11,697	
Wetlands	**Acreage**	
Upland freshwater	743	
Marine and intertidal	232	
Lakes	**Acreage**	
Class 1 Trout	60	
Class 1 Lawson	12.5	
Class 2 Woods	29	
Class 2 Zylstra	70	
Lakes and Freshwater Wetlands		**6%**
Streams	**Miles**	
Class 2	2.5	
Class 3	8.5	
Class 4/5	12	
Drainage runoff	**acre-feet**	
	3,154	

Table 24 Summary of current land use* in the False Bay Watershed

(Source: San Juan County 2000)

Classification	Acres	Percentage
Agriculture	3,741	12%
Timber Land	765	30%
Conservation	1,173	18%
Residential parcels (414)	2,666	23%
Public Lands	1.35	< 0.001%

* Current land use information is from the San Juan County Assessor's records.

D.1.3. Salmonid Utilization

A chum enhancement program was operated on this creek for several years but the results of this program have not been monitored (Hendrick pers. comm.). There currently is no known anadromous salmonid utilization of this system. Rainbow trout have been planted in lakes in this watershed but are not believed to be self-sustaining (Johnston pers comm.).

The known freshwater distribution of anadromous and resident salmonids is depicted in Appendix A.

D.1.4. Fish Access and Passage Barriers

A comprehensive barrier assessment survey has not been initiated and no data on barriers was located during the course of this investigation. There are a minimum of eight road crossing across San Juan Valley Creek.

D.1.5. Degradation of Riparian Conditions

San Juan Valley Creek flows through agriculture lands with a residential density of 40 acres per unit and most of the length has only limited natural riparian buffers (Kerwin pres. obs.).

D.1.6. Loss of Channel Complexity/Connectivity

USGS Quad maps indicate that numerous reaches of lower San Juan Valley Creek have been relocated and channelized. This includes almost all of the unnamed tributaries 02.0028, 02.0030, and portions of 02.0031. The land use adjacent to the lower reaches of San Juan Valley Creek is largely agriculture. The lower reaches of the creek and lower tributaries traverse through numerous agricultural fields and are unfenced for most of their route. This allows pastured animals direct access and results in continued riparian habitat degradation.

D.1.7. Altered Stream Hydrology/Flow

As mentioned previously, the principal water supply for the town of Friday Harbor and a constructed water reservoir used for agricultural purposes occur here. The soils of the valley bottom are highly saturated for a significant portion of the year, largely from surface water runoff originating from the surrounding hills and the generally low-lying topography of the basin floor. Under these conditions, surface water in the pastures is essentially flowing through and on top of the soil.

D.1.8. Water Quality

No water quality problems have been identified in this basin but sampling has been sporadic.

D.1.9. Biological Processes

There is anecdotal information from local long-term residents of small numbers of salmon historically being observed in this stream but currently there are no observations of salmon. Chum salmon carcasses have been observed at the mouth of San Juan Valley Creek (Pentilla pers. comm). The Washington Department of Fish and Wildlife Spawning Ground Survey Database does not contain any observations of salmon in this watershed.

Key Findings and Identified Habitat-limiting Factors

- The False Bay watershed is the largest watershed in the San Juan Islands
- The watershed has the largest amount of identified wetland acreage of all the watersheds in the county
- A field survey during the winter of 1997-98 suggested that most of the grazing fields were in fair condition, but some overgrazing and poor management was apparent
- There currently is no known anadromous salmonid utilization of this system.
- San Juan Valley Creek has only limited natural riparian buffers
- Numerous reaches of lower San Juan Valley Creek have been relocated and channelized
- There is anecdotal information of small numbers of salmon being observed in this stream but currently there are no observations of salmon.
- Chum salmon carcasses have been observed at the mouth of San Juan Valley Creek

Data Gaps

- A comprehensive barrier assessment survey has not been initiated and no data on barriers was located during the course of this investigation
- Water quality sampling has been sporadic.

D.2. Friday Harbor Watershed

D.2.1. Physical Description

Physical Description: The Friday Harbor watershed includes the Town of Friday Harbor, the only incorporated jurisdiction in San Juan County, and the Port of Friday Harbor.

Wetlands constitute over 11 percent of the Friday Harbor watershed. Much of the historic wetland is currently in agriculture use but some small remnants of natural wetlands remain. Salmon Creek (02.0019) (also known locally as Beaverton Creek) is the largest creek draining to Friday Harbor and enters Friday harbor near the University of Washington Marine Labs. There are two additional small stream systems that terminate in Friday Harbor including the Spring Street culvert which drains the Town of Friday Harbor and a second short drainage just north of Spring Street. There are no lakes present but there are several Class 3 ponds.

D.2.2.Watershed Condition

The largest contiguous area of impervious surfaces in the county is in Friday Harbor. Foot and vehicle traffic levels in Friday Harbor are very high as virtually all traffic to San Juan Island enters at this point. A large gravel pit is located between the south end of Friday Harbor and the north end of Griffin Bay. Extraction operations were closed in the spring of 1999. Water and oil separators are present in some of the newer storm drain installations, and some stormwater is treated, but most drains to the harbor do not have these separators. The Town of Friday Harbor adopted a Stormwater Management Plan in 1997 and created a stormwater utility district to fund upgrades in the stormwater system. It is currently upgrading portions of its storm sewer system.

Agriculture constitutes approximately 15 percent of the land use and is primarily pasture and hay land. Most of the lands in agriculture are located in or adjacent to wetlands. There is some harvestable timber in the watershed, mostly in the uplands. There are clearcut and thinned patches of forest evident. Tables 25 and 26 provide summaries of land use in this watershed.

Table 25: Summary of habitat types in the Friday Harbor Watershed (Source: San Juan County 2000**)**

Landcover Vegetation		Percentage
Grasses and Forbs	**1,747**	**29**
Dense Forest	**2,227**	**38**
Sparse Forest	**570**	**10**
Scrub	**966**	**16**
Watershed Acreage Total	**3,505**	
Wetlands	**Acreage**	
Upland freshwater	**398**	**11**
Marine and intertidal	**35**	
Lakes	**Acreage**	
None	na	
Lakes and Freshwater Wetlands		
Streams	**Miles**	
Class 2	0	
Class 3	**0.75**	
Class 4/5	**7**	
Drainage runoff	**acre-feet**	
	1,476	

Table 26: Summary of current land use* in the Friday Harbor Watershed

(Source: San Juan County 2000)

Classification	Acres	Percentage
Agriculture	491	14%
Timber Land	384	11%
Conservation	0	0 %
Residential parcels (782)	913	26%
Town of Friday Harbor	250	7%

*Current land use information is from the San Juan County Assessor's office and does not include commercial. The Town of Friday Harbor's 250 acres, 34% is commercial/industrial and 45% is vacant.

D.2.3. Salmonid Utilization

A chum enhancement program was operated on this creek for several years but the results of this program have not been monitored (Hendrick pers. comm.). There currently does not appear to be any anadromous salmonid utilization of this system.

The known freshwater distribution of anadromous and resident salmonids is depicted in Appendix A.

D.2.4. Fish Access and Passage Barriers

A comprehensive barrier assessment survey has not been initiated and no data on barriers was located during the course of this investigation.

D.2.5. Degradation of Riparian Conditions

In many locations, farm animals have access to the creek channel (Kerwin pers obs.) causing localized degradation to riparian habitats. During a survey in the winter of 1997-98, cattle, sheep, and some horses were observed with densities of between one and four animals per acre (San Juan County 2000). Standing water was observed on many fields during the winter rainy season. Beaverton Valley is largely in agricultural production and the riparian zones, where they exist, are not properly functioning.

D.2.6. Loss of Channel Complexity/Connectivity

USGS Quad maps show that numerous reaches of lower Salmon Creek have been relocated and channelized. This includes almost all of the unnamed tributaries 02.0022, 02.0020, 02.0020A and portions of 02.0023. The land use adjacent to the lower reaches of Salmon Creek is largely agriculture. The lower reaches of the creek and lower tributaries traverse through numerous agricultural fields and are unfenced for most of their route.

D.2.7. Altered Stream Hydrology/Flow

No information on stream flows was located during the course of this investigation. The soils of the valley bottom are highly saturated for a significant portion of the year due largely from surface water runoff originating from the surrounding hills and the generally low-lying topography of the basin floor. Under these conditions, surface water in the pastures is essentially flowing through and on top of the soil.

D.2.8. Water Quality

San Juan County has operated three sampling stations in the watershed. Stream water temperatures have ranged from 5.3 to 14.3°C during sampling in 1997 and 1998.

D.2.9. Biological Processes

There is anecdotal information from local long-term residents of small numbers of salmon historically being observed in this stream but currently there are no observations of salmon. The Washington Department of Fish and Wildlife Spawning Ground Survey Database does not contain any observations of salmon in this watershed. There were net pens present in Friday Harbor rearing salmon but that operation has been closed.

Key Findings and Identified Habitat-limiting Factors

- Most surface water drains to the harbor do not have these oil:water separators.
- The Town of Friday Harbor adopted a Stormwater Management Plan in 1997.
- There currently does not appear to be any anadromous salmonid utilization of this system
- In many locations, farm animals have access to the creek channel

- Beaverton Valley is largely in agricultural production and the riparian zones are not properly functioning
- Numerous reaches of lower Salmon Creek have been relocated and channelized

Data Gaps

- A comprehensive barrier assessment survey has not been initiated
- No data on stream flows was located during the course of this investigation

D.3. Egg, Trout and Sportsmans Lakes

D.3.1. Physical Description

Physical Description: Egg Lake, also historically known as Tucker Lake, is calculated at 6.6 acres in size with a depth of 17 feet (Wolcott 1973). Egg Lake, approximately 900 feet west of Sportsmans Lake drains into Sportsmans Lake via a connective marshy area. Sportsmans Lake is the largest lake on San Juan Island at 87 acres and a maximum depth of 11.5 feet. The natural lake was 66 acres in size and 10.0 feet deep but a permit (Permit # 230) allowed the lake level to be raised. Sportsmans Lake drains easterly to San Juan Channel via an unnamed stream according to Williams (1975) as stream number 02.0011. Unnamed stream number 02.0011 enters San Juan Channel via a naturally perched confluence that does not allow anadromous fish access. Several other smaller lakes and numerous wetlands drain into Sportsmans Lake.

Egg, Trout and Sportsmans Lakes are not accessible to anadromous fish but have been planted with rainbow trout. Large mouth bass are also present in Sportsmans Lake (Johnston pers. comm). The natural habitat in and around the lakes is not believed to be suitable for the natural production of salmonids although there is likely some natural reproduction of large-mouth bass in Sportsmans Lake and some of the mashes that are linked to the lake.

D.3.2. Watershed Condition

Agricultural uses in this watershed are continuing their historic presence with land gradually being converted to rural-residential use. The dominant agricultural use is livestock operations that include sheep, cattle, and horses (Kerwin pers obs.). A field survey during the winter of 2001 suggested that most of the grazing fields were in fair condition, but some overgrazing and poor management was apparent (Kerwin pers obs). During the winter most of the valley bottom fields are saturated with standing pools of water. During that same survey, some animals were being pastured through the winter with direct access to the creeks and saturated areas. No information was located during the course of this investigation that provided detailed summaries of land use in this watershed.

D.3.3. Salmonid Utilization

There is not any anadromous salmonid utilization of this system.

The known freshwater distribution of anadromous and resident salmonids is depicted in Appendix A.

D.3.4. Fish Access and Passage Barriers

A comprehensive barrier assessment survey has not been initiated and no data on barriers was located during the course of this investigation.

D.3.5. Degradation of Riparian Conditions

In many locations, farm animals have access to the creek channel (Kerwin pers obs.). During a survey in the winter of 2001, cattle, sheep, and some horses were observed with densities of between one and four animals per acre (Kerwin pers. obs). Standing water was observed on some of the valley fields during the winter rainy season. Outside of the agricultural areas, the riparian habitats generally appear to be in fair to good condition but no quantifiable data was located during the course of this investigation.

D.3.6. Loss of Channel Complexity/Connectivity

USGS Quad maps indicate that numerous reaches of short reaches of streams throughout this watershed have been relocated and channelized. These channel relocations are generally in the vicinity of road crossings or along property boundaries.

D.3.7. Altered Stream Hydrology/Flow

No information was located during the course of this investigation about changes in stream hydrology.

D.3.8 Water Quality

No information was located during the course of this investigation about changes in stream hydrology.

D.3.9 Biological Processes

This watershed was not historically available to anadromous fish due to natural barriers. The Washington Department of Fish and Wildlife Spawning Ground Survey Database does not contain any observations of salmon in this watershed.

Key Findings and Identified Habitat-limiting Factors

- The natural Sportsmans Lake was 66 acres in size and 10.0 feet deep but a permit (Permit # 230) allowed the lake level to be raised;
- There is not any anadromous salmonid utilization of this system;
- Livestock, in many locations, has direct access to the creek channel; and

- Numerous short reaches of streams throughout this watershed have been relocated and channelized.

Data Gaps

- No information was located during the course of this investigation that provided detailed summaries of land use in this watershed and
- No information was located during the course of this investigation about changes in stream hydrology.

CONCLUSIONS AND RECOMMENDATIONS

The objective of this report was to provide an understanding of the habitat factors that may limit the natural salmonid production in the nearshore ecosystem of the San Juan Islands. A second purpose was to provide assistance in guiding nearshore watershed planning and salmon recovery actions in WRIA 2. This report provides a snapshot-in-time of the available information concerning nearshore habitats and selected freshwater watersheds that effect salmonids in WRIA 2. We have attempted to cover most of the published and unpublished literature available on the region. However, a general lack of nearshore ecosystem data limited the ability to provide a more in-depth review and analysis.

We have also incorporated applicable information from sources outside of the study area. This was done in an attempt to provide a more complete understanding of the nearshore habitats. Many of the plant and animal species, ecosystem processes, habitat types, and stressors found in WRIA 2 occur in other areas and, in some instances, better information has been developed in those areas. The geopolitical boundaries themselves represent artificial limitations and habitats in the WRIA 2 nearshore ecosystem are a part of the larger landscapes. This condition requires an examination beyond watershed and geopolitical boundaries for an understanding of how the nearshore ecosystem functions, what influences natural functions, and how that translates into an understanding of ecosystem health.

The conclusions and recommendations sections of this report were developed in an attempt to summarize and interpret the meaning of this report and to provide recommended actions that are likely to lead to the preservation of and improvement of ecosystem health. In order to draw conclusions and recommendations from this report, and for interested parties to understand the context, it is critical to comprehend the approach used in preparing the report and the guiding principles and assumptions made in the development of conclusions and recommendations. The assumptions used in this report to generate conclusions and recommendations include:

- The development of conclusions and recommendations uses “Best Available Science”. Best Available Science is defined here as a combination of direct studies, professional observation, expertise and experience, and the application of fundamental ecological principles (Note: this definition is currently under review and is expected to change). It is also important to note here that the 1995 Washington State Legislature added a new section to the Growth Management Act (GMA) to ensure that counties and cities consider reliable scientific information when adopting policies and development regulations to designate and protect critical areas. The new GMA section, RCW 36.70A.172, requires all counties and cities in Washington to include the best available science in developing policies and development regulations to protect the functions and values of critical areas. In addition, they must give special consideration to conservation or protection measures necessary to preserve or enhance anadromous fisheries. Additional information on this subject is detailed in the Land Use chapter of this report.

- The nearshore ecosystem of WRIA 2 is an integral part of the total watershed and is influenced by both upland and marine processes. In the marine environment, the nearshore ecosystem of WRIA 2 should be viewed as a part of the continuum from freshwater to the open ocean and include processes across those landscapes.
- Humans exhibit an increasing power/ability to modify natural ecosystem processes, structure and functions, often to the detriment of living plant and animal species and ecosystem processes.
- Modification (i.e., habitat alteration and resource extraction) of natural ecosystem processes and structure is likely to result in shifts in species composition, viability, and productivity.
- The preservation of the nearshore ecosystem in WRIA 2 is likely to be good for anadromous salmonids because of their dependence on properly functioning nearshore conditions for feeding, refuge, and migration as juveniles and adults.
- Factors that influence the nearshore ecosystem of WRIA 2 occur from outside the WRIA. These include regional and global-scale factors such as climate variability.

The development of conclusions and recommendations should include the following:

- Interpret what is currently known about the nearshore.
- Identify the following:
  - Those particular plant and animal communities, populations, or other elements of the ecosystem that require special attention;
  - Additional information that is needed to improve our understanding of the ecosystem.
- Recommend the following:
  - Coordinated actions that will preserve, protect, and, as necessary enhance the nearshore ecosystem;
  - Actions that will enhance our understanding of nearshore ecosystem processes, structure, and functions.
- Provide a realistic assessment and predictions about the current and future health of the nearshore ecosystem. The assessment and predictions need to be revealing about the potential consequences of our actions and activities, or lack thereof, in light of our current knowledge and understanding.

This report and these recommendations were written from a technical perspective to provide technical guidance. Every attempt was made to answer the technical question "What is wrong?" and avoid answering the policy question of "How do we do to fix it?". Every effort was made to avoid evaluation and interpretation of political, policy, and social considerations in both the report and in the conclusions and recommendations. However, there are some social values (i.e., human health and safety, commercial value) that are identified but were not evaluated in this report. These considerations are the responsibility of other groups that may use this report in their planning and policy deliberations.

Conclusions

- In WRIA 2, the nearshore ecosystem performs a critical role in supporting a wide variety of biological resources, many of which are important to the people of the region for economic, recreational, cultural, aesthetic, and other social values.

- The interactive effect of anthropogenic caused changes and natural variability on processes and resources has not been studied.

- The cumulative effects of multiple stressors, or individual stressors over various temporal and spatial scales, or the synergistic effects of stressors on nearshore habitats are unstudied in a systematic way.

- There are numerous data gaps in our understanding of the nearshore ecosystem that directly inhibit or weaken our ability to make informed decisions regarding management of the system. Monitoring programs are limited and have been inadequate for providing the level of scientific information necessary for informed resource management decisions.

- There is a general lack of coordination in the collection, analysis, and dissemination of nearshore data.

- The nearshore system of the San Juan Islands needs more focused attention with funded research.

- The nearshore must be addressed from an ecosystem perspective.

- Action is needed in the nearshore.

Numerous studies and reports have previously identified the problems facing the nearshore environment (i.e., PSWQA 1988a,b; Shreffler and Thom 1993; West 1997; WADOE 1994; Broadhurst 1998; Lynn 1998; PSWQAT 1998; WADNR 2000; PSWQAT 2000), and have drawn conclusions similar to this report. Yet, while a multitude of natural resource management agencies and other stakeholders have long recognized the importance of the San Juan Island resources and the effects of anthropogenic impacts, the response to previous recommendations for improved protection of resources is and has been lacking. Protection, restoration and recovery actions have lagged while the human population and development have increased. A general lack of appropriate and adequate levels of protection has led to significant declines of nearshore species and habitats. The most obvious signs of loss include the Endangered Species Act listings of Hood Canal Summer Chum salmon, Puget Sound Chinook salmon, Bull trout (Washington’s only native char), a petition to list Coho salmon, and a proposal to list the marine system’s top predator, the orca whale.

Particular attention and protective standards need to focus on communities, populations, or other elements of the ecosystem that require special attention. Salmon populations are only one example. While salmon have become the major driver for our recent planning and assessment work, due to regulatory (i.e., ESA) and social demands, they are certainly not the only indicator of ecosystem health and may or may not be the best indicator. They may, however, be a useful indicator due to their complex life history and utilization of the landscape. While freshwater reproduction and rearing is critical to their survival, it is also important to emphasize that the Pacific salmon of Washington have a marine life history trajectory that is dependent upon good estuarine and marine habitat conditions and prey resources. This dependency requires us to pay particular attention to other elements in the ecosystem. For example, forage fishes found in the San Juan Islands (i.e., surf smelt, sand lance, herring) are important prey for salmon and a multitude of other marine species, yet we have no population data for surf smelt and sand lance and do little to protect their spawning habitat. Likewise, it has been suggested that harpacticoid copepods, another primary prey item of juvenile salmonids, may be an ecologically meaningful organism for determining environmental quality in nearshore environments (Cordell and Simenstad 1988).

Other examples of nearshore ecosystem elements that play critical roles and should be protected include: eelgrass and macroalgae, both of which provide critical habitat functions for numerous animal species including different portions of their life histories; the natural erosion of banks and bluffs, which provide a critical habitat forming process for crab, clam, and other invertebrate populations or communities that play important roles in the nearshore ecosystem. Often times, for these later species, life history data are limited. These are only a few examples and as such are not intended to be exclusive of other species, populations, communities, and other elements of the ecosystem. As previously stated, establishing additional baseline monitoring and assessment, an understanding of ecosystem linkages and the impacts of anthropogenic influences are critical to identifying the most important elements of the ecosystem and providing recommendations for protection.

Recommendations

Based on the findings and conclusions previously detailed in this report, it is evident that there are a several general and specific actions that should be taken for us to better understand and protect individual elements within the WRIA 2 nearshore ecosystem. For example, it is clear that several anthropogenic influences are responsible for habitat degradation and loss. However, we lack the scientific knowledge to fully understand and describe all of the complex ecosystem linkages necessary to provide specific remedies for maintaining or restoring “proper functioning conditions” for all elements, at all levels within the ecosystem. Therefore, it is essential that we identify and prioritize the most critical data gaps, habitats, species, and ecosystem processes for future analysis. This objective will require developing criteria and protocols for evaluating each of these elements prior to analysis. In addition, it is also essential that we take early actions to prevent further harm (*primum non noceo*). It is also imperative that we not wait as additional scientific information is generated. Early actions can come in many forms and range from the development of a coordinated technical framework and conceptual models to implementing a range of conservation, restoration, and protection actions or standards.

Protection is the most important early action that can be taken, for without it, degradation will continue and future restoration, scientific investigation, and other efforts to understand and restore the ecosystem will likely not reach recovery goals. Furthermore, with respect to protection, the certainty of success is much higher than restoration and the cost of protection, in terms of biological and economic costs, is low relative to the cost of restoration. This point is of significant concern because restoration methodologies are not well studied and costly restoration projects have typically been poorly monitored for success. Monitoring and adaptive management must be integral elements of both short-term and long-term action agendas to allow for the integration of new information.

It is important to note that the following action recommendations are divided into specific, <u>non-prioritized</u> categories. We often approach these types of action recommendations in a very linear fashion. However, many of these actions may be, and should be, taken simultaneously to restore the nearshore ecosystem. Although this report was written for a specific geographic area, many of these recommendations apply elsewhere and will require coordination and implementation on a larger scale to preserve and restore nearshore ecosystem conditions.

Monitoring and Research

- Develop, fund, and implement a coordinated monitoring and research program for the nearshore. This will require careful resource considerations (i.e., staff and funding at appropriate levels) and participation from entities outside of San Juan County to address issues at the appropriate temporal and spatial scales;
- Develop a technical framework for understanding how the nearshore fits into the landscape of WRIA 2 and Puget Sound as a whole;
- Work towards the establishment and support the development of a consortium of entities concerned with the nearshore environment and develop a long-term funding source for nearshore research and projects; and
- Develop criteria and protocols for monitoring and assessment that may be used at various temporal and spatial scales that are widely accepted and may be used for research, protection, preservation, and restoration.

Habitat Protection, Enhancement, and Restoration

- Protect the existing undeveloped shoreline areas in WRIA 2 from development practices that would be detrimental to the nearshore ecosystem;
- Develop protection, acquisition, and incentive strategies for lands that would contribute to maintaining or restoring ecosystem processes and functions to the benefit of nearshore ecosystem health;
- Enforce existing habitat protection regulations;
- Protect forage fish spawning areas and other upper intertidal habitats and species. Concentrate restoration efforts on areas with shoreline armoring and other

development practices that reduce ecological processes and functions that support habitat quality.

- Protect eelgrass and macroalgae beds from the adverse effects of shoreline modifications;
- Protect and enhance marine riparian vegetation. In the development of standards for protection, and restoration, consider multiple habitat functions;
- Identify critical areas for protection, restoration, in WRIA 2. Then protect and restore them; and
- Recreate intertidal acreage such as marshes, flats, and other habitats.

Reduction of Shoreline Modifications

Shoreline Armoring

- Critically review new installations of shoreline armoring in an effort to determine need; and
- Develop and implement technical guidance for alternatives to traditional shoreline armoring that maintain natural shoreline processes and functions.

Filling

- Reduce the amount of existing shoreline fill that has resulted from shoreline development practices and shoreline armoring;
- Prevent new fill in the nearshore; and
- Where existing fill is removed, restore the area to low-gradient habitats such as flats, marshes, beaches, and backshore.

Overwater Structures

- Protect and light penetration in the nearshore;
- Enhance light penetration under existing overwater structures as opportunities become available (i.e.: during replacement);
- Eliminate the use of construction materials and construction practices that release environmental contaminants into the aquatic environment (i.e., treated wood products such as pilings and other structural components of docks and piers); and
- Remove existing sources of environmental contaminants (i.e., treated piles and old floats) where it is determined that their removal will not release additional contaminants.

Water Quality

- Identify and control non-point pollution sources;

- Reduce, or preferably, eliminate point-source contaminants; and
- Develop innovative methods of stormwater treatment, such as projects that use plantings of native vegetation to filter stormwater and retain sediments while improving fish and wildlife habitat.

Non-native Species

- Monitor for and prevent the introduction of non-indigenous and invasive species. Identify and eliminate sources of introductions; and
- Eliminate non-indigenous and invasive species where present or limit their spread.

Recreational Impacts

- Minimize or eliminate habitat impacts associated with the harvest of nearshore species and other recreational uses of nearshore habitats.

As a final note, it must be recognized that the ability to preserve and improve nearshore ecosystem health and address the recommendations contained in this report will require a number of changes in the way we as residents and stewards "do business" and live. Only through recognizing and acknowledging the influences that we have on the processes, structure and functions of this ecosystem can we develop meaningful avoidance and protection standards. Providing adequate resources (i.e.: funding) and a framework for the development of new information, management strategies, and preservation will require a large-scale, coordinated effort that integrates various management efforts and crosses geo-political and other jurisdictional boundaries. Taking an ecosystem approach to understanding and managing nearshore resources is essential. These are but a few of the necessary elements that are needed to improve the quality of the nearshore ecosystem.

Despite the fact that the San Juan Islands are truly islands, it must be recognized that influences from outside the Islands impact much of the nearshore habitats. Many of the same recommendations, as well as additional recommendations, should be applied to adjacent and nearby watershed which exert influences on the nearshore habitats of the San Juan Islands.

While recognizing that there have been recent changes in regulatory and management practices, and our level of scientific knowledge has increased in recent years, the impacts of development have continued to effect nearshore resources. From the larger Puget Sound perspective, it is revealing to review environmental regulations, or mitigation actions, and compare them to the level of protection they have actually provided in the nearshore environment. Considering the levels of habitat loss and degradation in the nearshore, they have not proven to be adequate. These concerns are not new, as are most of the conclusions and recommendations found in this report. For example, upon review of recent past proceedings of Puget Sound Research Conferences (1988; 1991; 1995; 1998; and 2001), these same issues surface time and time again. Likewise, reports from the Puget Sound Water Quality Authority (PSWQA) (1990), Puget Sound Water Quality (PSWQAT) Action

Team (i.e., Broadhurst 1998; West 1997; Lynn 1999), Puget Sound/Georgia Basin Task Force (1994), WADNR (2001), and WDFW White Papers (i.e., Williams et al., 2001; Nightengale et al. 2001), identify habitat losses and causes of habitat degradation. Interestingly, the problems, findings and recommendations contained in PSWQA (1990) apply just as much today as they did over twelve years ago. Lists of non-prioritized problems and findings from this report are listed below:

Identified Problems

1. There is no systematic fish and wildlife habitat inventory for the San Juan Island basin.
2. Habitat protection in the San Juan Islands is frequently limited by gaps in interagency coordination and program integration.
3. Even when protection is provided, support for long-term monitoring to gauge its effectiveness is often lacking.
4. We lack an ecosystem approach to habitat management in the San Juan Islands.
5. We lack state and local goals and policies for habitat protection in the San Juan Islands with incentives to achieve that protection.
6. The public lacks awareness, understanding, and involvement in habitat protection issues and programs.
7. Enforcement of existing habitat protection laws in the San Juan Islands is inconsistent.
8. We lack adequate funding for current and new programs that protect fish and wildlife habitat in the San Juan Islands.

Findings

1. We lack clear federal, state and local goals and policies for habitat protection in the San Juan Islands.
2. A number of problems need to be jointly addressed and solved by a wide variety of agencies, governments (including federally recognized treaty tribes), organizations, and individuals currently involved in actions affecting the management and protection of fish and wildlife habitat.
3. Federal and state agencies responsible for managing fish and wildlife habitats in the San Juan Islands do not have sufficient authority to adequately protect these habitats.
4. Agencies and local jurisdictions responsible for implementing the Growth management Act often do not recognize and/or incorporate protection of the nearshore ecosystem in the planning and regulatory process.
5. The public lacks awareness and understanding of habitat protection issues and programs in the San Juan Islands.
6. We lack adequate public involvement in issues relating the protection of fish and wildlife habitat in the San Juan Islands.
7. The resources for staffing adequate habitat review, inventory, monitoring, enforcement, and education efforts are inadequate.

GLOSSARY

4(d) Rule – (ESA Section): The protective rule promulgated by the lead federal agency at the time it makes a final decision to list a species as threatened. This rule is developed only for a single species at a time. The content of a 4(d) rule may be a restatement of Section 9(a) prohibitions on **take** of a species, but also may specify activities which have been determined to be adequately regulated and therefore can be given legal coverage for the **incidental take** of the listed species.

Abandoned side-channels: typically formed when a channel avulsion causes the river to move from its former route.

Adaptive management: Monitoring or assessing the progress toward meeting objectives and incorporating what is learned into future management plans.

Adfluvial: Life history strategy in which adult fish spawn and juveniles subsequently rear in streams but migrate to lakes for feeding as subadults and adults. Compare fluvial.

Aggradation: The geologic process of filling and raising the level of the streambed or floodplain by deposition of material eroded and transported from other areas.

Anadromous fish: Species that are hatched in freshwater, mature in saltwater, and return to freshwater to spawn.

Aquifer: Water-bearing rock formation or other subsurface layer.

Backbar channels: overflow channels located on the apex of point bars, frequently wetted during moderately high flows, and generally do not support perennial vegetation. Multiple backbar channels may form across the top of a point bar as a result of lateral accretion of sediment during high flow events.

Baseflow: That component of streamflow derived from groundwater inflow or discharge. Can be presented in a variety of measurement units including: cubic feet per second (cfs) and inches (in).

Basin: The area of land that drains water, sediment and dissolved materials to a common point along a stream channel.

Basin flow: Portion of stream discharge derived from such natural storage sources as groundwater, large lakes, and swamps but does not include direct runoff or flow from stream regulation, water diversion, or other human activities.

Bioengineering: Combining structural, biological, and ecological concepts to construct living structures for erosion, sediment, or flood control.

Biological Assessment: Information prepared by or under the direction of the lead federal agency concerning listed and proposed species and designated and proposed critical habitat that may be present in the action [i.e., project] area and the evaluation of potential effects of the action on such species and habitat [50 CFR 404.02]; this assessment would be evaluated by the federal agency and the results potentially incorporated into a Biological Opinion.

Biological Diversity (biodiversity): Variety and variability among living organisms and the ecological complexes in which they occur; encompasses different ecosystems, species, and genes.

Biotic Integrity: Capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region; a system's ability to generate and maintain adaptive biotic elements through natural evolutionary processes.

Biological Opinion: Part of the Section 7 consultation process, a written statement provided to the affected federal agency that details how the reviewed action affects the species or its critical habitat. If jeopardy or adverse modification of **critical habitat** is found to be a result of the activity the opinion will contain suggestions for reasonable and prudent alternatives for that action which would minimize its impacts and allow the activity to proceed [Endangered Species Habitat Conservation Planning Handbook].

Biological oxygen demand: Amount of dissolved oxygen required by decomposition of organic matter.

Braided stream: Stream that forms an interlacing network of branching and recombining channels separated by branch islands or channel bars.

Buffer: An area of intact vegetation maintained between human activities and a particular natural feature, such as a stream. The buffer reduces potential negative impacts by providing an area around the feature that is unaffected by this activity.

Candidate Species: Under US Fish and Wildlife Service regulations, "those species for which the Service has on file sufficient information on biological vulnerability and threat(s) to support proposals to list them as endangered or threatened species [but] [p]roposal rules have not yet been issued because this action is precluded…". For those species under the jurisdiction of National Marine Fisheries Service (NMFS), this term refers to a species for which concerns remain regarding their status, but for which more information is needed before they can be proposed for listing. Species protections, e.g., prohibitions on take, provided by the ESA do not apply to candidate species [Endangered Species Habitat Conservation Planning Handbook].

Carrying capacity: Maximum average number or biomass of organisms that can be sustained in a habitat over the long term. Usually refers to a particular species, but can be applied to more than one.

Channelization: Straightening the meanders of a river; often accompanied by placing riprap or concrete along banks to stabilize the system.

Channelized stream: A stream that has been straightened, runs through pipes or revetments, or is otherwise artificially altered from its natural, meandering course.

Channel stability: Tendency of a stream channel to remain within its existing location and alignment.

Check dams: Series of small dams placed in gullies or small streams in an effort to control erosion. Commonly built during the 1900s.

Confluence: Joining.

Connectivity: Unbroken linkages in a landscape, typified by streams and riparian areas.

Critical Stock: A stock of fish experiencing production levels that are so low that permanent damage to the stock is likely or has already occurred.

Depressed Stock: A stock of fish whose production is below expected levels based on available habitat and natural variations in survival levels, but above the level where permanent damage to the stock is likely.

Debris torrent: Rapid movements of material, including sediment and woody debris, within a stream channel. Debris torrents frequently begin as debris slides on adjacent hillslopes.

Degradation: The lowering of the streambed or widening of the stream channel by erosion. The breakdown and removal of soil, rock and organic debris.

Deposition: The settlement of material out of the water column and onto the streambed.

Distinct Population Segment (DPS): A portion of the overall population of a species which is both a discrete and significant part of that population. "Discrete" means that the group in question is separated from others due to physical, physiological, ecological, or behavioral factors, or if it is separated by a jurisdictional boundary that denotes significant differences in protective mechanisms for the species. "Significant" means that, at least, 1) the discrete group in question persists in an ecological setting unusual or unique for the species; 2) loss of the discrete group would create a significant gap in the range of the species; 3) the discrete group represents the only natural occurrence of a species that may be more abundant elsewhere as an introduced population outside its historic range; or 4) the genetics of the discrete group differ markedly from that of other populations of the species. This term is used by United States Fish and Wildlife Service (USFWS) in its status determinations for inland salmonid populations [61 FR 4721].

Distributaries: Divergent channels of a stream occurring in a delta or estuary.

Diversity: Variation that occurs in plant and animal taxa (i.e., species composition), habitats, or ecosystems. See *species richness.*

Drainage Area: the area, measured in a horizontal plane, which contributes surface runoff to a stream gage.

Ecological restoration: Involves replacing lost or damaged biological elements (populations, species) and reestablishing ecological processes (dispersal, succession) at historical rates.

Ecosystem: Biological community together with the chemical and physical environment with which it interacts.

Ecosystem management: Management that integrates ecological relationships with sociopolitical values toward the general goal of protecting or returning ecosystem integrity over the long term.
Endangered Species Act: A 1973 Act of Congress that mandated that endangered and threatened species of fish, wildlife and plants be protected and restored.

Endangered Species: Means any species, [including subspecies or qualifying distinct population segment] which is in endanger of extinction throughout all or a significant portion of its range other than a species of the Class Insecta as determined by the Secretary to constitute a pest whose protection under would provide an overwhelming and overriding risk to man.

Escapement: The number of fish that have survived all causes of mortality and will make up the spawning population.

Estuarine: A partly enclosed coastal body of water that has free connection to open sea, and within which seawater is measurably diluted by fresh river water.

Eutrophic: Water body rich in dissolved nutrients, photosynthetically productive, and often deficient in oxygen during warm periods. Compare *oligotrophic.*

Evolutionary Significant Unit (ESU): A definition of a species used by National Marine Fisheries Service (NMFS) in administering the Endangered Species Act. An ESU is a population (or group of populations) that is reproductively isolated from other conspecific population units, and (2) represents an important component in the evolutionary legacy of the species.

Extinct Species: A species no longer present in its original range or as a distinct species elsewhere.

Extirpation: The elimination of a species from a particular local area.

Factor of Decline: Natural and anthropogenic induced factors that contribute to the decline of salmonids. These not only include climate and ocean conditions and natural predation but also the factors that are more commonly thought to be within human control such as habitat modification, harvest, hatchery practices and introduction of non-native species.

Flood: An abrupt increase in water discharge.

Floodplain: Lowland areas that are periodically inundated by the lateral overflow of streams or rivers.

Flow regime: Characteristics of stream discharge over time. Natural flow regime is the regime that occurred historically.

Fluvial: Pertaining to streams or rivers; also, organisms that migrate between main rivers and tributaries. Compare *adfluvial*.

Freshet: A sudden increase in stream discharge that results from the rapid melting of accumulated snow.

Gabion: Wire basket filled with stones, used to stabilize streambanks, control erosion, and divert stream flow.

Genetic Diversity Unit (GDU) is defined as: A group of genetically similar stocks that is genetically distinct from other such groups. The stocks typically exhibit similar life histories and occupy ecologically, geographically and geologically similar habitats. A GDU may consist of a single stock.

Geomorphology: Study of the form and origins of surface features of the Earth.

Glides: Stream habitat having a slow, relatively shallow run of water with little or no surface turbulence.

Harm: Defined in regulations implementing the ESA as an act "which actually kills or injures" listed wildlife. Harm may include "significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering"

Healthy Stock: A stock of fish experiencing production levels consistent with its available habitat and within the natural variations in survival for the stock.

Hydrograph: Chart of water levels over time.

Hydrology: Study of the properties, distribution, and effects of water on the Earth's surface, subsurface, and atmosphere.

Hydromodification: The channelization and armoring of natural banks to prevent flooding or protect stream adjacent property and structures from erosion; navigation activities (ditching, dredging and channel straightening); anthropogenic alterations in channel morphology (planform, cross-sectional area, bed and bank configuration); and anthropogenic changes in the amount of in-channel LWD.

Intermittent stream: Stream that has interrupted flow or does not flow continuously. Compare *perennial stream*.

Intraspecific interactions: Interactions within a species.

Jeopardy: A determination, reached through the consultation process, that an activity would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species

Large Woody Debris (LWD): Large woody material that has fallen to the ground or into a stream. An important part of the structural diversity of streams. LWD is also referenced to as "coarse woody debris" (CWD). Either term usually refers to pieces at least 20 inches (51 cm) in diameter.

Limiting Factor: Single factor that limits a system or population from reaching its highest potential.

Mg/L: milligrams per liter. For dissolved oxygen concentrations in water it may also be expressed as ppm.

Macroinvertebrates: Invertebrates large enough to be seen with the naked eye (e.g., most aquatic insects, snails, and amphipods).

Mass failure: Movement of aggregates of soil, rock and vegetation down slope in response to gravity.

Mile measurement: A nautical mile.

Native: Occurring naturally in a habitat or region; not introduced by humans.

Non-Point Source Pollution: Polluted runoff from sources that cannot be defined as discrete points, such as areas of timber harvesting, surface mining, agriculture, and livestock grazing.

Nearshore marine zone: Habitats that lie between the lower limit of the photic zone (approximately at minus 30 meters MLLW) and the upland–aquatic interface.

Outermost upland: Those lands not covered by water during an ordinary high tide.

Ppm: Parts per million, for dissolved oxygen it may also can be expressed as mg/L

Parr: Young trout or salmon actively feeding in freshwater; usually refers to young anadromous salmonids before they migrate to the sea. See *smolt*.

Plunge pool: Basin scoured out by vertically falling water.

Properly Functioning Condition (PFC): State of the physical, chemical, and biological aspects of watershed ecosystems which will sustain a healthy salmonid population(s). Properly functioning condition generally defines a range of values for several measurable criteria rather than specific, absolute values. The range for these values may vary from watershed to watershed based upon a variety of factors, e.g., geology, hydrology, and stream geomorphology, and the improved understanding of how these factors shape ecosystem functions.

Rain-on-snow events: The rapid melting of snow as a result of rainfall and warming ambient air temperatures. The combined effect of rainfall and snow melt can cause high overland stream flows resulting in severe hillslope and channel erosion.

Rearing habitat: Areas required for the successful survival to adulthood by young animals.

Recovery: The process by which the decline of an endangered or threatened species is arrested or reversed, and threats neutralized so that its survival in the wild can be ensured. The goal of the ESA is for the recovery of listed species to levels where protection under the ESA is no longer necessary.

Redds: Nests made in gravel (particularly by salmonids); consisting of a depression that is created and the covered.

Resident fish: Fish species that complete their entire life cycle in freshwater.

Riffle: Stream habitat having a broken or choppy surface (white water), moderate or swift current, and shallow depth.

Riparian: Type of wetland transition zone between aquatic habitats and upland areas. Typically, an area on or by land bordering a stream, lake, tidewater, or other body of water.

Riprap: Large rocks, broken concrete, or other structure used to stabilize streambanks and other slopes.

River mouth: The waters of any river or stream, including sloughs and tributaries, upstream and inside of a line projected between the outermost uplands at the mouth.

Rootwad: Exposed root system of an uprooted or washed-out tree.

SASSI: Salmon and Steelhead Stock Inventory.

SSHIAP: A salmon, steelhead, habitat inventory and assessment program directed by the Northwest Indian Fisheries Commission.

Salmonid: Fish of the family salmonidae, including salmon, trout chars, and bull trout.

Salmon: Includes all species of the family Salmonid

Sediment: Material carried in suspension by water, which will eventually settle to the bottom.

Sedimentation: The process of sediment being carried and deposited in water.

Side channel: A portion of an active channel that does not carry the bulk of stream flow. Side channels may carry water only during high flows, but are still considered part of the total active channel.

Sinuosity: Degree to which a stream channel curves or meanders laterally across the land surface.

Slope stability: The degree to which a slope resists the downward pull of gravity.

Smolt: Juvenile salmon migrating seaward; a young anadromous trout, salmon, or char undergoing physiological changes that will allow it to change from life in freshwater to life in the sea. The smolt state follows the parr state. See *parr*.

Stock: Group of fish that is genetically self-sustaining and isolated geographically or temporally during reproduction. Generally, a local population of fish. More specifically, a local population – especially that of salmon, steelhead (rainbow trout), or other anadromous fish – that originates from specific watersheds as juveniles and generally returns to its birth streams to spawn as adults.

Stream order: A classification system for streams based on the number of tributaries it has. The smallest unbranched tributary in a watershed is designated order 1. A stream formed by the confluence of 2 order 1 streams is designated as order 2. A stream formed by the confluence of 2 order 2 streams is designated order 3, and so on.

Stream reach: Section of a stream between two points.

Stream types:

Type 1: All waters within their ordinary high-water mark as inventoried in "Shorelines of the State".

Type 2: All waters not classified as Type 1, with 20 feet or more between each bank's ordinary high water mark. Type 2 waters have high use and are important from a water quality standpoint for domestic water supplies, public recreation, or fish and wildlife uses.

Type 3: Waters that have 5 or more feet between each bank's ordinary high water mark, and which have a moderate to slight use and are more moderately important from a water quality standpoint for domestic use, public recreation and fish and wildlife habitat.
Type 4: Waters that have 2 or more feet between each bank's ordinary high water mark. Their significance lies in their influence on water quality of larger water types downstream. Type 4 streams may be perennial or intermittent.
Type 5: All other waters, in natural water courses, including streams with or without a well-defined channel, areas of perennial or intermittent seepage, and natural sinks. Drainage ways having a short period of spring runoff are also considered to be Type 5.

Sub Watershed: One of the smaller watersheds that combine to form a larger watershed.

Thalweg: Portion of a stream or river with deepest water and greatest flow.

Wall-base channels: groundwater-fed side-channels typically found at the base of a steep sideslope. Wall base channel may form as seepage that emerges from the base of the slope converges and flows toward the mainstem or they may represent former river channels that have been abandoned.

Watershed: Entire area that contributes both surface and underground water to a particular lake or river.

Watershed rehabilitation: Used primarily to indicate improvement of watershed condition or certain habitats within the watershed. Compare *watershed restoration*.

Watershed restoration: Reestablishing the structure and function of an ecosystem, including its natural diversity; a comprehensive, long-term program to return watershed health, riparian ecosystems, and fish habitats to a close approximation of their condition prior to human disturbance.

Watershed-scale approach: Consideration of the entire watershed in a project or plan.

Weir: Device across a stream to divert fish into a trap or to raise the water level or divert its flow. Also a notch or depression in a dam or other water barrier through which the flow of water is measured or regulated.

Wild Stock: A stock that is sustained by natural spawning and rearing in the natural habitat regardless of origin.

ACRONYMS and ABBREVIATIONS

ac-ft	acre feet
°C	degrees Centigrade
cfs	cubic feet per second
CC	Washington Conservation Commission
CSO	Combined sewer overflow
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
ESA	Endangered Species Act
° F	degrees Fahrenheit
LWD	Large Woody Debris
MSL	Mean Sea Level
NMFS	National Marine Fisheries Service
NWIFC	Northwest Indian Fisheries Commission
ppt	parts per thousand
OFM	Washington State Office of Financial Management
RM	River Mile
SaSI	Salmonid Stock Inventory
SASSI	Salmon and Steelhead Stock Inventory
USGS	United States Geological Survey
USFWS	United States Fish and Wildlife Service
WDF	Washington Department of Fisheries (superceded by WDFW)
WDFW	Washington Department of Fish and Wildlife
WDOE	Washington Department of Ecology
WDNR	Washington Department of Natural Resources
WDW	Washington Department of Wildlife (superceded by WDFW)
WRIA	Water Resources Inventory Assessment
WWTIT	Western Washington Treaty Indian Tribes

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APPENDIX A

The Known and Presumed Freshwater Distribution of Salmonids in the San Juan Islands (WRIA 2)

Click on the following Topic(s) to be linked to the associated map.

Known Coho and Sea Run Cutthroat Distribution

Known Resident Fish

Nearshore Forage Fish

APPENDIX B

NEARSHORE HABITAT TYPES
IN THE SAN JUAN ISLANDS

Click on the following Topic(s) to be linked to the associated map.

Shoreline Armoring Features

Shoreline Armoring Percentages

Shoreline Type

BC Coastal Class Shoretypes

Estuarine Intertidal Shoretypes

Marine Intertidal Shoretypes

Habitat/Bio-Exposure Classification

Pressence of Kelp

Percent Riparian Cover

Riparian Condition

Seagrass

Saltmarsh Vegetation

Sargassum Muticum

Marsh Distribution

APPENDIX C

National Marine Fisheries Service Puget Sound Evolutionary Significant Units (ESUs)

Click on the following Topic(s) to be linked to the associated map.

Chinook ESU

Coho ESU

Cutthroat ESU

Steelhead ESU

Appendix D

19th Century U. S. Coast and Geodetic Nautical Charts
Of The San Juan Islands